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ANNUAL PROGRESS REPORT

1994

Water Management Research Laboratory
Agriculture Research Service
U.S. Department of Agriculture
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INTRODUCTION

The overall mission of the Water Management Research Laboratory is to conduct research and develop advanced water management practices, methods, equipment, and systems to utilize soil, water, nutrients, and energy resources efficiently and to improve sustainability and productivity in irrigated agriculture under water-limited conditions.

This Annual Research Progress Report is intended to inform our many collaborators and cooperators and any other interested researchers and agricultural practitioners about progress made on our research projects in 1994 and plans for 1995. It is our intent to keep the individual reports short but informative, focusing on objectives, approaches, summarized results and future plans for the project.

Many of these projects are carried out in cooperation with personnel at the U.S. Salinity Lab in Riverside, CA, the U.S. Cotton Research Station at Shafter, CA, and the University of California at Riverside and Davis. Cooperative projects were funded by the California Department of Water Resources (DWR) and the State Water Resource Control Board, the Imperial Irrigation District (IID), the Metropolitan Water District (MWD) of Southern California and the Imperial Valley Conservation Research Center Committee (IVCRCC), Pima Grow, and Vicksburg Chemical.

If you have questions or desire additional information, please contact the principle scientist or myself. We welcome comments on our ongoing research as well as suggestions on water management research that you feel we should be doing. Thank you for your continuing interest and support.

THOMAS J. TROUT
Research Leader

MANAGEMENT RESEARCH LABORATORY STAFF

I. Federal Employees	Position
1. Scientists	
Trout, Thomas	Incoming Research Leader Agricultural Engineer
Ayars, James	Acting Research Leader, Agricultural Engineer
Hutmacher, Robert	Plant Physiologist
Banuelos, Gary	Plant/Soil Scientist
Avishalom Marani	Visiting Scientist, Israel
Richard Soppe	Visiting Scientist, The Netherlands
2. Technical Support/Full Time	
Clark, David	Electronics Engineer
Dale, Frank	Hydrologic Technician
Davis, Kenneth	Soil Scientist
Dettinger, David	Machinist
Downey, Steve	Biological Technician, Plants
Hawk, Carl	Biological Technician, Plants
Mead, Richard	Soil Scientist
Peters, Merle	Biological Technician, Plants
Pflaum, Tom	Chemist
Schoneman, Richard	Agricultural Engineer
Vail, Sue	Biological Technician, Plants
Zambrzuski, Stella	Biological Technician, Plants
Technical Support/Temporary Part Time	
Ament, Colleen	Biological Technician
Nevarez, Arthur	Electronics Technician
Penland, Jason	Biological Technician
Piyasil, Fawn	Biological Technician
Samra, Parmijit	Biological Technician
Trent, Jessica	Biological Technician
Yue, Ronggui	Biological Technician
3. Administrative Support	
Karen Nichols	Secretary
Paula Lynch	Secretary

MANAGEMENT RESEARCH LABORATORY STAFF

II. Part-Time Student Assistants

1. Research Support Agreement (Fresno State University Foundation)

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Diaz, Debbie	Laboratory Technician	G. Bañuelos
Covarrubias, Joel	Field Research Technician	B. Hutmacher
Ehn, Erik	Research Apprentice	B. Hutmacher
Herrera, Nick	Research Apprentice	J. Ayars
Jimenez, Jorge	Reseach Apprentice	B. Hutmacher
Kandola, Paramjit	Reseach Apprentice	G. Bañuelos
Litman, Vanessa	Reseach Apprentice	G. Bañuelos
Liu, Jee	Field Research Technician	B. Hutmacher
Rajashekar, Geeta	Laboratory Technician	T. Pflaum
Schuck, Jim	Research Apprentice	J. Ayars

WATER MANAGEMENT RESEARCH LABORATORY COLLABORATORS

Collaborator	Affiliation
Aung, L.H.	USDA, ARS, Postharvest Quality/Genetics, Fresno, CA
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Weir, B.	UC Cooperative Extension, Merced, CA
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Williams, L.	Kearney Agricultural Center, Parlier, CA
Wu, L.	University of California, Davis, CA
Zick, M.	Cedar Chemical Co., Fresno, CA

BRITZ PROJECT WATER TABLE RESPONSE

R.A. Schoneman, J.E. Ayars, F. Dale

OBJECTIVE: To monitor water table levels in the Southern Field (section 1) of the study site during a first irrigation event.

METHODS: Perimeter observation wells were measured for water table depths before and after the initial irrigation of an oat crop in section 1 of the Britz project site. Well measurements were taken 01-Dec 93. The irrigation took place between 02-Dec and 12-Dec-93. Observation well measurements were again taken 07-Dec when the irrigation was two-thirds complete. No rain fell during this time period. A tailwater sump located along the western edge of the monitored field had been empty for at least two weeks prior to the irrigation, and remained empty after completion. The quarter-section was irrigated with gated pipe in 102 cm rows 805 m long. Water meter readings indicated that 23 cm were applied. For comparison, the north field of the experiment was not irrigated and was idle (fallow) during this time period. Perimeter wells around this field were also measured at the same times as the rest.

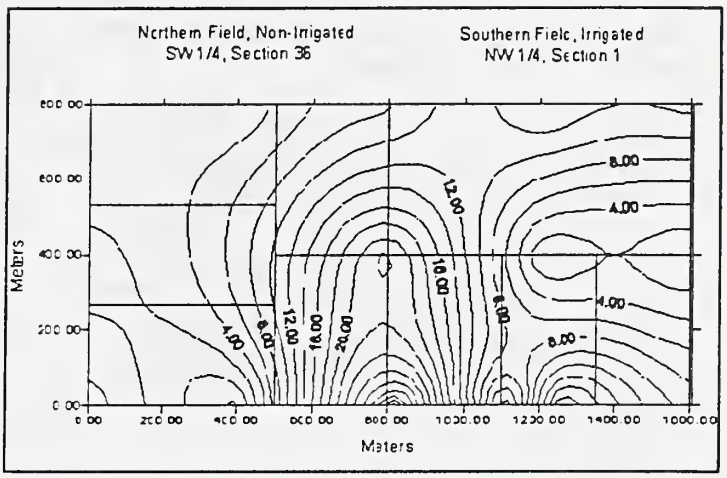


Figure 1. Rise in ground water table level in cm.

RESULTS: The water table rose in response to the irrigation event. Confirmation that the irrigation caused this effect was from the lack of rain and ponding in the tailwater sump along the west edge of the field. Moreover, surrounding fields were also idle when this irrigation occurred.

A computer program was used to plot isolevel lines on a map of the irrigated and non-irrigated fields. Each line represents points where the ground water level changed an equal amount. The map of figure 1 indicates that ground water levels rose approximately six times higher in the irrigated field than in the non-irrigated field.

When ground water levels rise, oxygen is driven out of these layers in the soil profile and naturally-occurring salts and other elements are washed into the ground water table. This process can bring higher salinity (and elemental) concentrations closer to the surface and reduce the available productive regions in the soil profile. The map also shows that the ground water level changes migrated into the northern field as well, indicating the importance of applying water management techniques over an area, and not on just a field basis.

FUTURE PLANS: These data will be written in a report to the cooperator. The project has been terminated and WMRL equipment removed.

BRITZ PROJECT OAT CROP

R.A. Schoneman, J.E. Ayars, F. Dale

OBJECTIVES: To monitor cooperator activities of applied water and yield for the Oat crop of the final season at the project site. Only the southern field (nw 1/4, section 1) was planted.

METHODS: The crop was planted 28-Nov-93. Irrigation was by gated aluminum pipe in rows spaced at 102 cm and 805 m long. Propeller-driven meters were installed in the pipelines to record water runs. Ranch records were consulted for yield figures. Rainfall was recorded at the Westlands weather station of the CIMIS network (6.4 km distant). Harvest by combine occurred 28-May-93.

RESULTS: Germination irrigation occurred 01-Dec to 12-Dec-93. One additional irrigation was applied 20-Mar to 28-Mar-94. Total water applied by irrigation was 279 mm. Rainfall recorded was 134 mm. Yield was 5.6 Mg/ha.

FUTURE PLANS: The project was terminated and equipment removed before harvest of the oats.

PARLIER LYSIMETERS II: INSTRUMENTATION

James E. Ayars, Richard Mead, Dave Clark, Dave Dettinger, Richard Soppe

OBJECTIVE: Construct and install the necessary equipment to control the water table depth in one soil tank, to measure the evapotranspiration, to control the subsurface drip irrigation system used in the lysimeter, to measure the groundwater contribution to the crop water requirement, to monitor the root development in the soil profile, and to measure the soil water content.

PROCEDURES: The water table depth will be controlled using a Mariotte bottle which was constructed using two lengths of 30 cm diameter pipe. The bottle was fitted with a ultrasonic depth measuring instrument. The schematic of this equipment is shown in figure 1. The depth gauge will be used to measure the depth of water lost each hour and to control the filling of the tanks each night at midnight. Root development will be monitored using mini-rhizitron tubes installed horizontally, in one end of each soil tank. (fig 2). The soil water content will be measured using radio frequency capacitance (RF) equipment installed in horizontal and vertical access tubes. The horizontal tubes are installed in the opposite ends of the soil tanks from the mini-rhizitron tubes.(fig 2). The placement of the vertical access tubes for a neutron probe and the RF capacitance equipment is shown in figure 2. The dead load on the scale has been eliminated using a counter balance and the active weight will be measured using a load cell. The weight will be measured every hour and used to compute the weight loss and thus the evapotranspiration. The system will be controlled using a Campbell CR-7 data acquisition and control system. Irrigation using a subsurface drip system will be done after a threshold value of 1 mm ET is reached. The irrigation supply tanks are an integral part of the lysimeter system and are thus accounted for in the weight change calibrations. The supply tanks will be filled each night at midnight and the scale weight will be re-initialized. The data acquisition and control will be fully automated and linked to the Water Management Research Laboratory offices through a telephone modem.

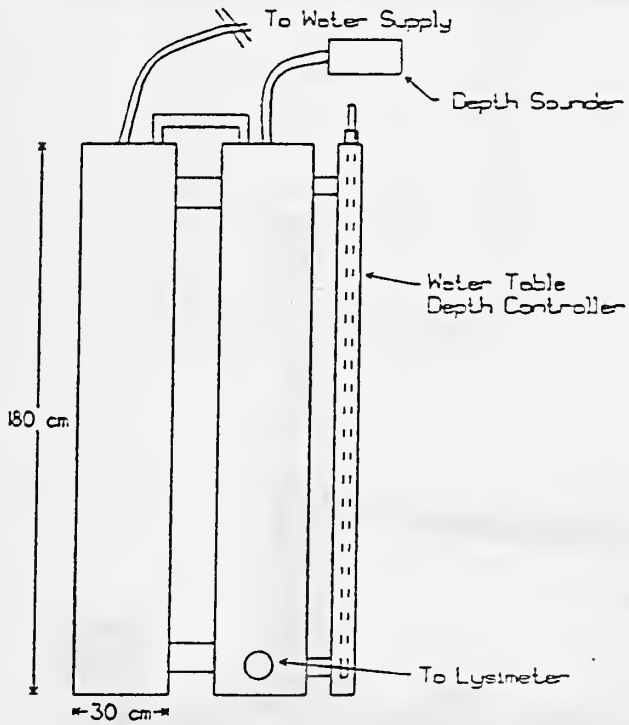


Figure 1. Schematic of Mariotte Bottle used to control water table depth in lysimeter.

RESULTS: The Mariotte bottle has been constructed and installed as have the control and data acquisition and irrigation system. The system is being tested in preparation for use in the Spring of 1995. Tensiometer, neutron probe and Sentek access tubes have been installed from the surface. Data from the tensiometers will be used along with changes in the soil water content to calculate the hydraulic conductivity.

FUTURE PLANS: Continue the development of the automated data and control system and use it to monitor and control experiments at this facility.

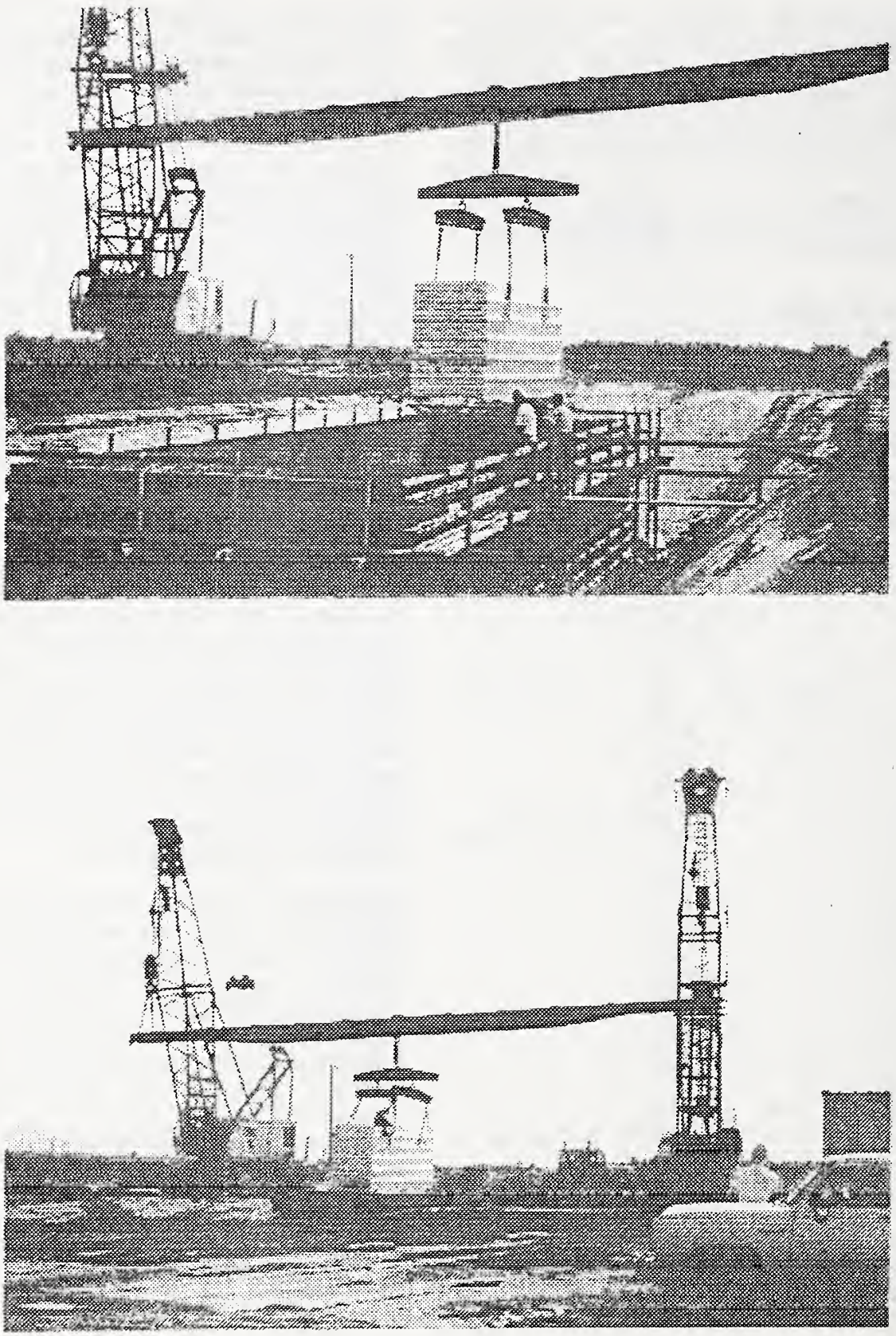


Figure 2. Moving Parlier soil tanks into place.

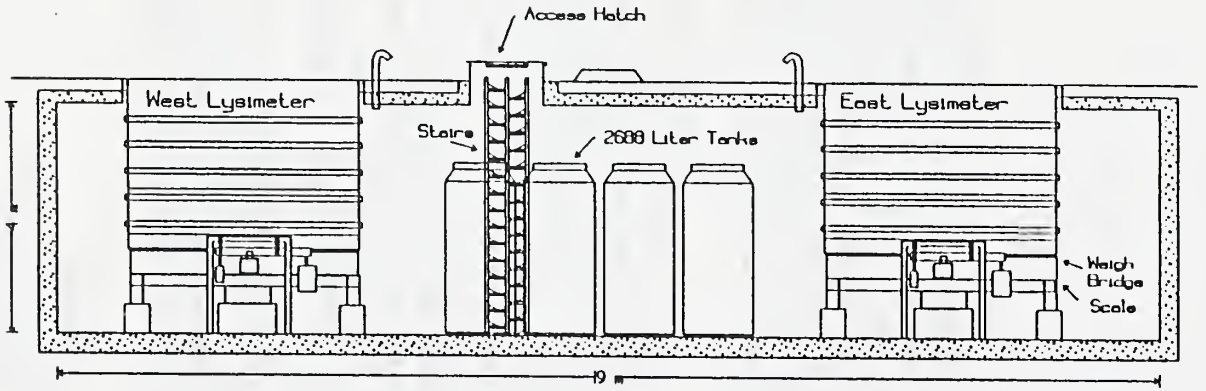


Figure 1a. Side view of Parlier lysimeter facility.

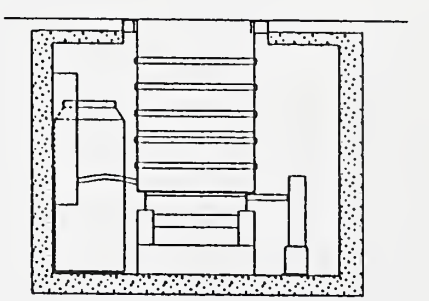


Figure 1c. End view of Parlier lysimeter facility.

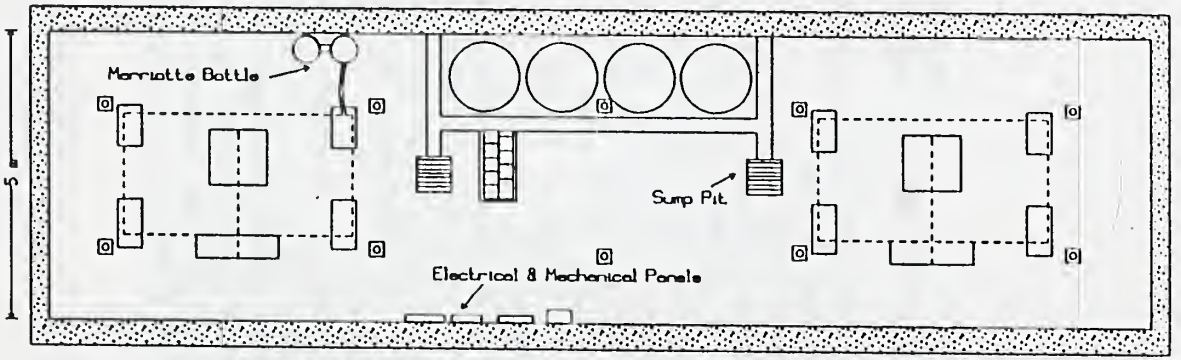


Figure 1b. Plan view of Parlier lysimeter facility.

PARLIER LYSIMETERS I: CONSTRUCTION

James E. Ayars, Dave Dettinger, Richard Soppe,
Richard Schoneman, Frank Dale

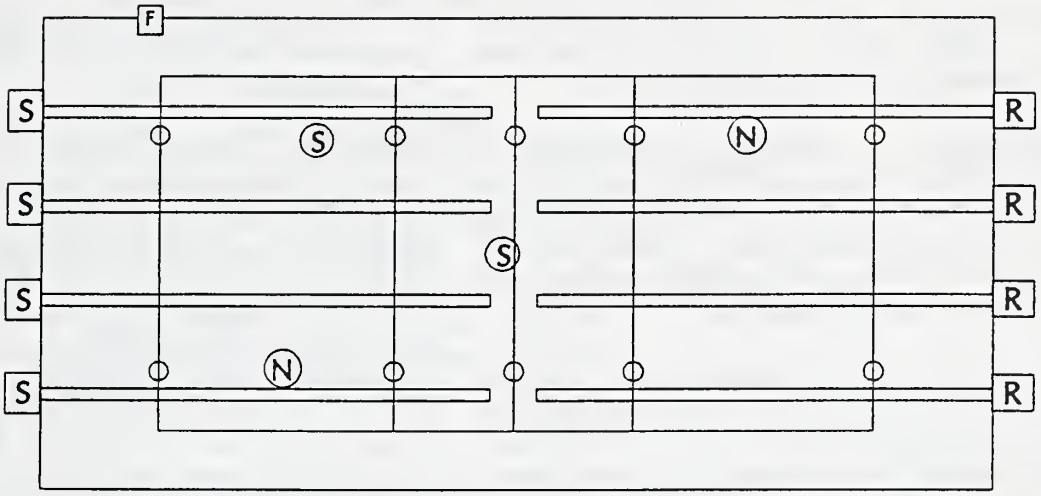
OBJECTIVE: Complete the construction of the facility to house the two 2m by 4m by 3m soil tanks being used in shallow groundwater management research.

PROCEDURES: The design of the facility was completed by the architectural firm of Lew and Patnaude located in Fresno, CA. The contract was put out for bid in October of 1993 and the contract was let in January of 1994. The successful bidder was D and S Construction of Selma, CA. The soil tanks were filled in 1993 and moved to the site for the installation of horizontal access tubes for soil water measurement and root observation.

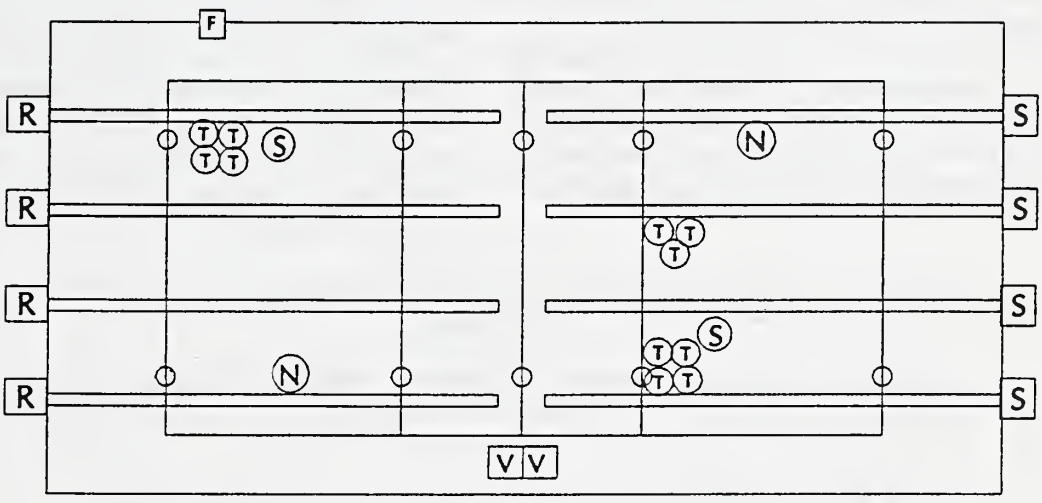
RESULTS: A cross-sectional view of the lysimeter facility is given in figure 1a. The facility houses both the soil monoliths and scales as well as four 2600 liter tanks used to store the water supply for the shallow groundwater, and the Mariotte bottle used to control the water table water table depth. Access is provided on all sides of each monolith with adequate access in the central part of the facility to use video equipment to observe root development. The facility is provided with an exhaust system to maintain humidity levels. Construction was begun on February 28, 1994 with the excavation of the site. The monoliths were installed April 14, 1994 and the facility was accepted by the government on July 28, 1994. The plan view of the site is shown in figure 1b and an end view is shown in figure 1c. The movement of the soil tanks into place is shown in figure 2. Each soil tank weighed 42 Mg and two 90 Mg cranes were used to support a tank in the center of the beam and then move it into place. Following the acceptance of the facility, the wiring and experimental equipment were installed.

FUTURE: The first experiments will be run in 1995.

West Lysimeter



East Lysimeter



Legend

- Drip Emitter
- F — Flush Out Valves
- N — Neutron Probe Tube (vertical installation)
- S — Sentek Sensor (vertical installation)
- T — Tensiometer (vertical installation)
- R — Root Observation Tube (horizontal installation)
- S — Sentek Sensor (horizontal installation)
- V — Valve Stem Ports

Figure 2.

BROADVIEW PROJECT I. PLANT RESPONSE

R. A. Schoneman, J. E. Ayars, J. Trent, B. Novak, K. Carusso

OBJECTIVE: Characterize Plant response to water table control procedures instituted in the experimental field.

METHODS: Tomato (Lycopersicon esculentum - Apex 1000) was planted 14-16 - Feb - 94 in SE 1/4, Section 13 of the Broadview Water District. Hand harvest occurred 09-Aug-94 and machine harvest followed on 12-22-Aug-94.

Three areas were chosen to monitor leaf water potential (LWP) trends during the growing season. Locations were chosen on the basis of observation well data taken early in the season which indicated where shallow, medium, and deep ground water levels could be expected. Within each area, three locations were identified for LWP measurements. At each location, a minimum of three third or fourth stem position leaves were sampled, transported to the measurement chamber in covered, painted, moist containers, and processed. The device used a pressure chamber to induce reverse migration of leaf moisture out the cut end of the petiole. This procedure was carried out from 06-Jul-94 to 02-Aug-94.

RESULTS: Figure 1 shows trends of leaf water potential in the experimental field. Area "S" maintained the lowest LWP readings. Area "M" measurements were 11% higher, and area "D" were 22% higher. Corresponding ground water table levels for these areas during this time period displayed a similar variation. A variation of 1.5 to 2.2 m depth to ground water occurred in area "S", a 1.8 to 2.6 variation developed in area "M", and a 2.2 to 2.6 m variation was found in area "D". These data suggest that the crop in the shallow area was getting some water from shallow groundwater.

FUTURE PLANS: A more generalized pattern of observation wells will be installed in the field next season. Control of the ground water table will be repeated with the next crop in the cooperator's rotation - cotton. LWP levels will be monitored again.

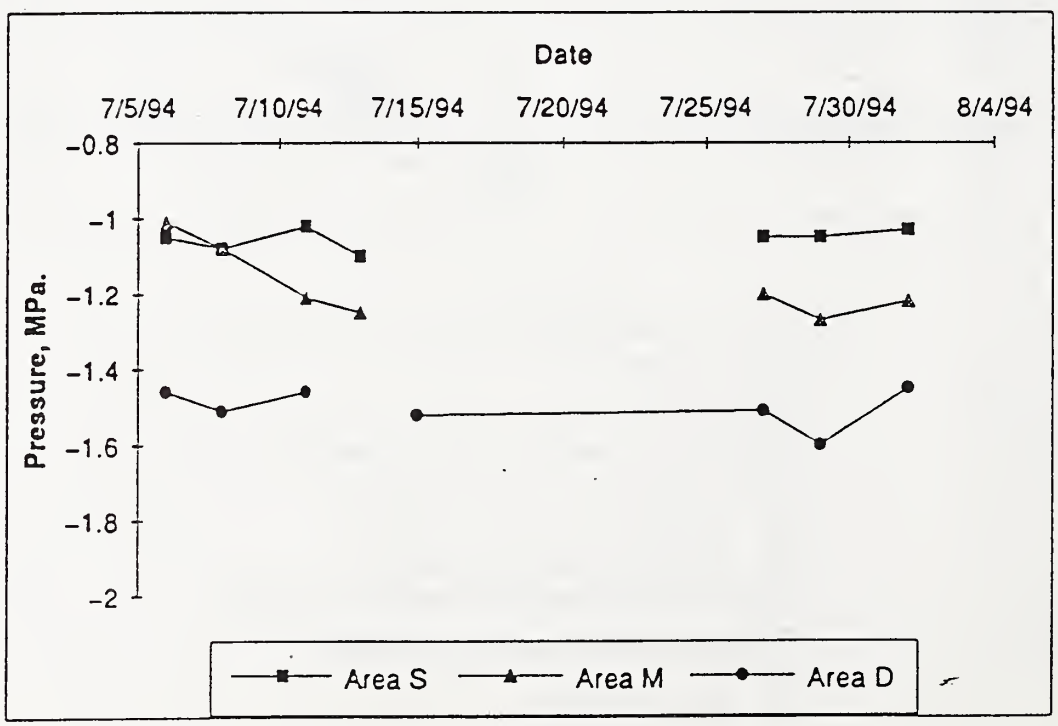


Figure 1. Leaf Water Potential Trends Broadview Project.

BROADVIEW PROJECT II. WATER BALANCE SUMMARY

R. A. Schoneman, J. E. Ayars, F. Dale, B. Novak

OBJECTIVE: Tabulate applied water for the experimental site in 1994.

METHODS: The Water District installed meters in pipelines to monitor applied water. Surface runoff water was reused. Rainfall amounts were obtained from district records. The adjacent CIMIS station does not reliably record rainfall.

RESULTS: Table 1 lists the irrigation events, irrigation method used, and total applied (by method and for the season). A rainfall total is also shown.

FUTURE PLANS: A new CIMIS station is being constructed in the area and will be accessed for rain and Eto data in May-95 when it comes on line. Discussions are being initiated to determine feasibility of techniques to separate out drain flow for the experimental site.

Table 1. Tomato Crop 13–4.

Date	Event	Depth Applied Inches	Depth Applied mm
2/19/94	Sprinkler	3.2	81
3/1/94	"	4.3	109
3/14/94	"	2.7	69
4/17/94	Gated pipe/furrow	5.8	147
5/25/94	"	5.4	137
6/9/94	"	2.0	51
6/17/94	"	3.0	76
6/25/94	"	1.7	43
	Total Applied	28.1	714
	Total Sprinklers	10.2	259
	Total Gated Pipe	17.9	455
	Total Rainfall	5.85	149

BROADVIEW PROJECT III. WATER TABLE RESPONSE TO CONTROL

R. A. Schoneman, J. E. Ayars, F. Dale,
J. Trent, B. Novak, K. Carusso

OBJECTIVE: Record water table levels and correlate to control measures.

METHODS: Water table levels were measured through the growing season with a sounder attached to a tape measure in 38 mm diameter observation wells installed in a pattern illustrated in figure 1a and 1b. Drain valves were turned on and off and weir boards installed in manholes according to the pattern shown in table 1. Figure 2 shows locations and types of control. The observation well measurements were plotted with a computer program and are shown in figure 3.

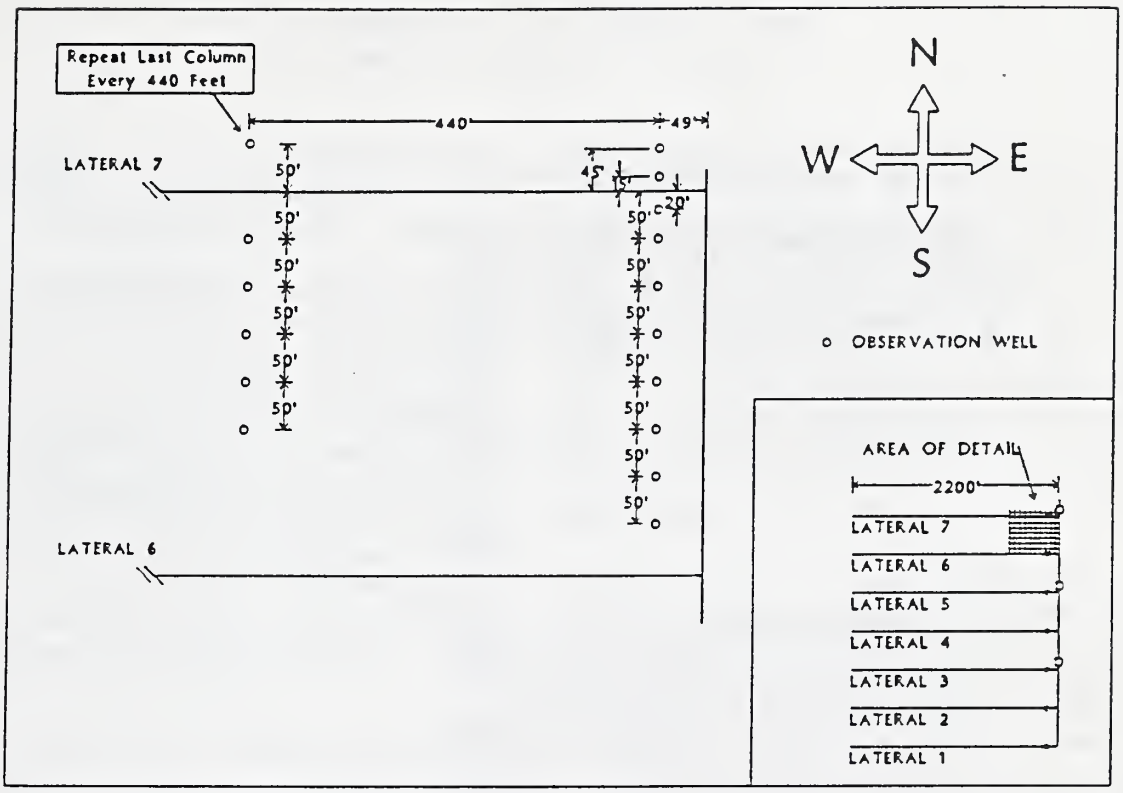
RESULTS: Early season watertable control caused concern by the cooperator that the crop appeared to be showing oxygen deficiency. The drain lateral controls were opened and the problem was alleviated. Control instead was achieved by inserting weir boards in the manhole at the north edge of the site where effects would be seen over the entire field. Figure 3 shows how the water table responded in the closely-monitored areas designated S, M, and D (described in other reports of this project in this publication). Depth to ground water remained at 1.5 m or more until the beginning of July and 2.25 or more until harvest in mid Aug-94.

Table 1. Control scheme.

Date	4/29/94	5/2/94	5/3/94	5/19/94	5/20/94	5/24/94
Drain no.						
7	C	C	C	O	O	O
6	C	C	C	C	O	O
5	C	C	C	C	O	O
4	C	C	C	C	O	O
3	C	C	O	O	O	O
2	3 Open	O	O	O	O	O
1	Open to first mark.				O	O
MH#1	O	O	O	O	O	O
MH#2	O	3	3	3	3	2
MH#3	O	4	4	4	4	5

Notes:
1 This configuration remained in place until harvest.
2 1 – 2" x 12" Board.
3 2 – 2" x 12" Board.
4 2 – 2" x 12" and 1 – 2"x 6" Boards.
5 2 – 2" x 12" and 2 – 2"x 6" Boards.
C = Fully closed.
O = Fully open.
MH= Manhole.

FUTURE PLANS: Control options will be evaluated with cotton next year.



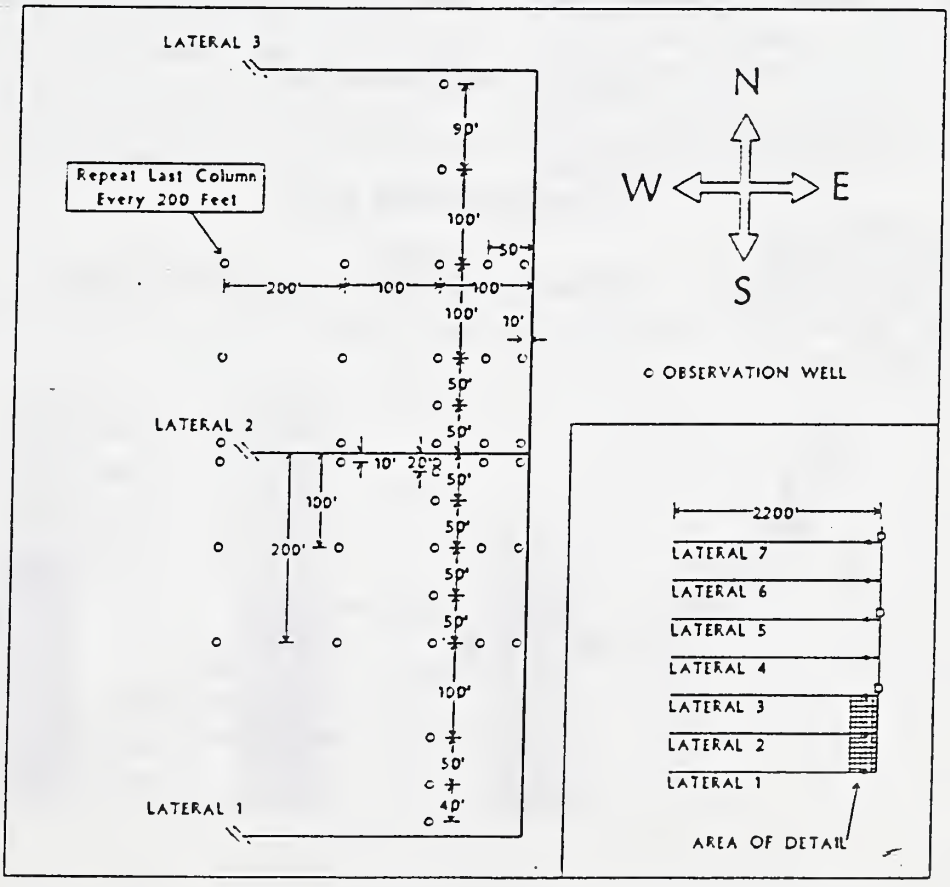


Figure 1. Observation well map.

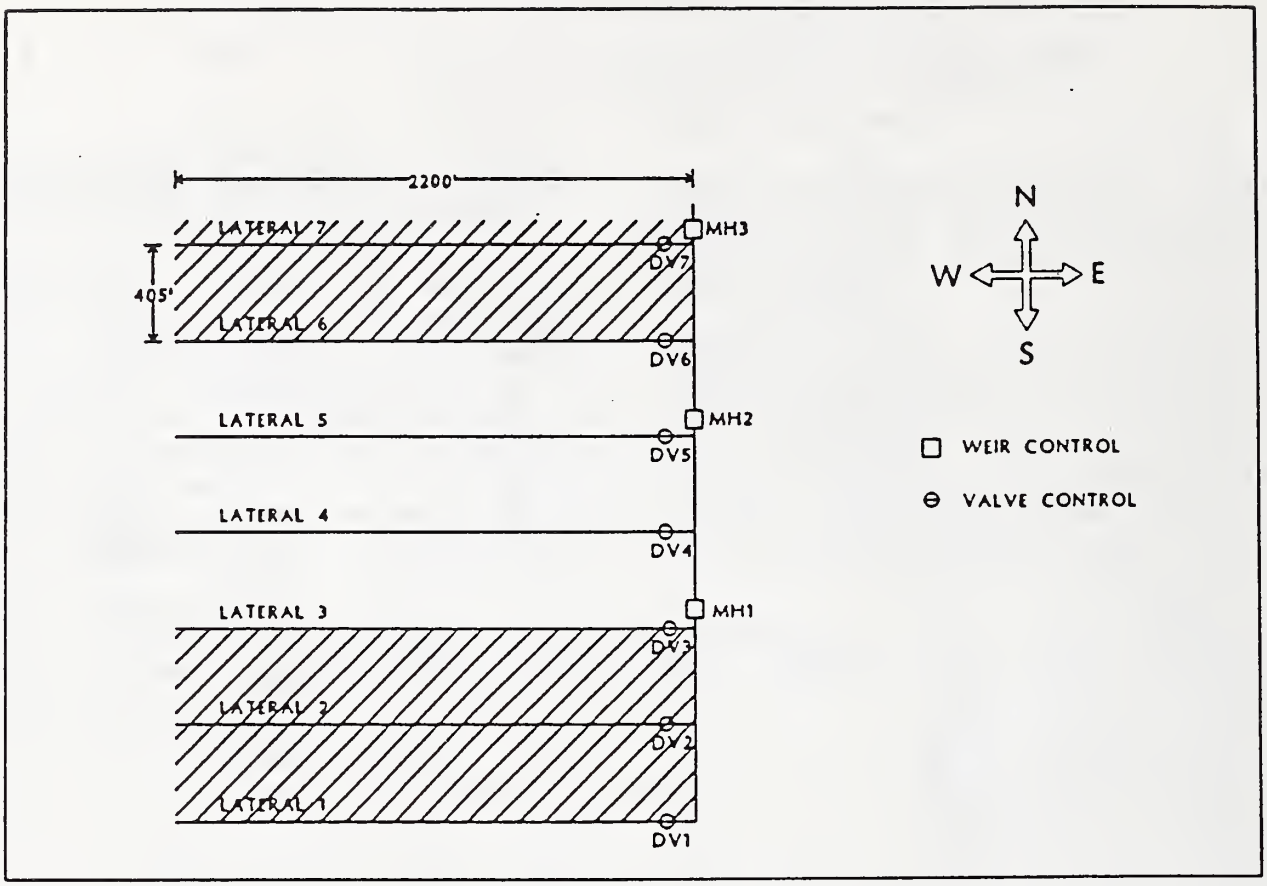


Figure 2. Control Structure Map.

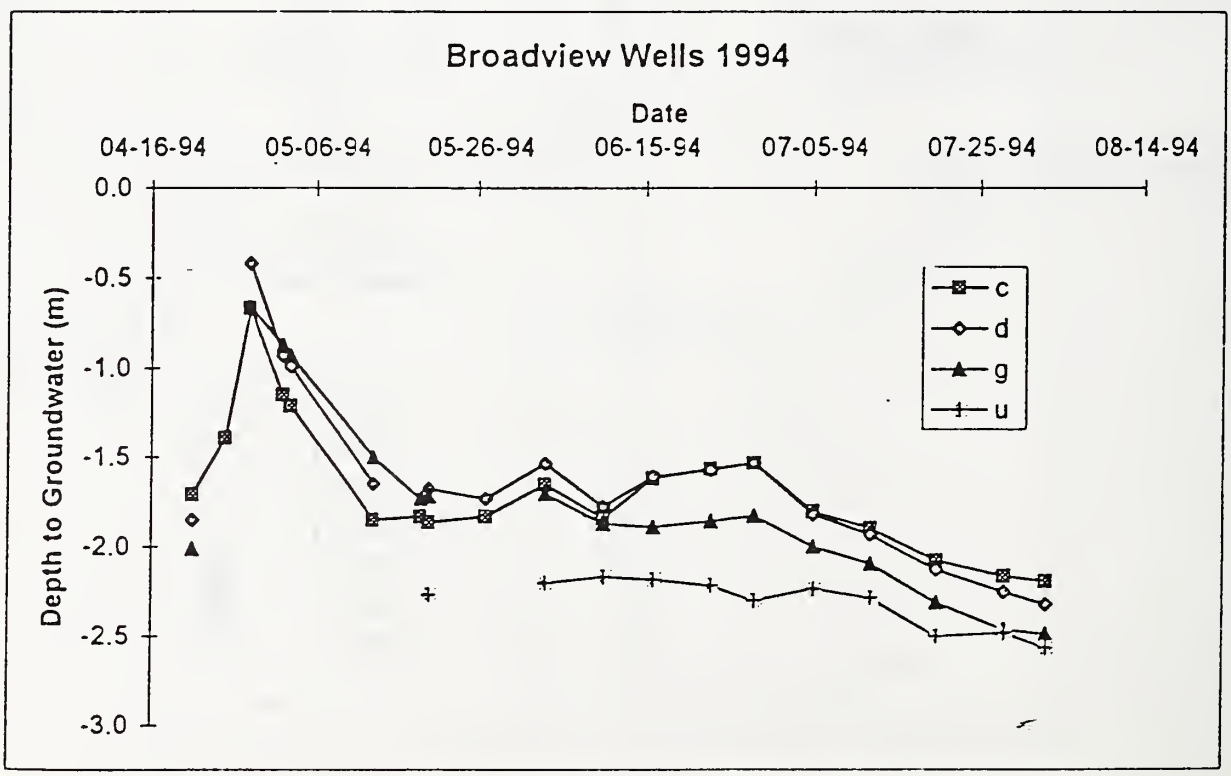


Figure 3. Depth to water table seasonal trends.

BROADVIEW PROJECT IV. YIELD CHARACTERISTICS

R. A. Schoneman, J. E. Ayars, F. Dale,
J. Trent, B. Novak, K. Carusso

OBJECTIVE: List yield components for tomato (lycopersicon esculentum - Apex 1000) at the experimental site.

METHODS: The crop was hand-harvested 09-Aug.-94. In each of the sample areas (designated S for shallow, M for medium, and D for deep watertable depth), three row lengths (20 ft.- 6 m.) were marked and the plants cut off at ground level. Sorting tables were used to separate large green, large red, small green, small red, and limited use fruit for weighing. Bucket weights of each category were measured on a tripod-mounted scale. These data were graphed and are shown in figure 1. Table 1 lists the numerical data.

Table 1. Numerical data for sample areas hand-harvested 09-Aug.-94.

Metric T./Ha. Area	Large Red	Small Red	Large Green	Small Green	Limited Use	Total Red
S	81.70	34.58	1.29	3.66	5.81	116.29
M	68.19	45.33	2.69	2.87	9.17	113.52
D	16.05	46.62	0.29	1.29	23.47	62.67

RESULTS: Total red fruit production was virtually the same in areas S and M. Area D showed a 45.5% reduction in the same production categories. Limited use fruit was found to be approximately 3 times higher in area D than in the other two areas. Large and small green fruit quantities were very nearly equal in area M. In areas S and D, there were more small green than large green fruit. Area D showed the least fruit in both green categories.

Plants in Area D were observed to be drying up and changing color as compared to the other two areas, S and M, where plants still showed green. The plants in area D did not have the benefit of a shallow ground water resource as reported elsewhere in this publication. Without moisture to extend plant life, the fruit matured and then began deteriorating, increasing amounts of limited use category fruit. Areas S and M produced more large red fruit as a result of longer plant life. More time was available to increase size and bring these fruit to maturity.

FUTURE PLANS: Yield will be monitored next year for the cotton crop to assess water table control effects.

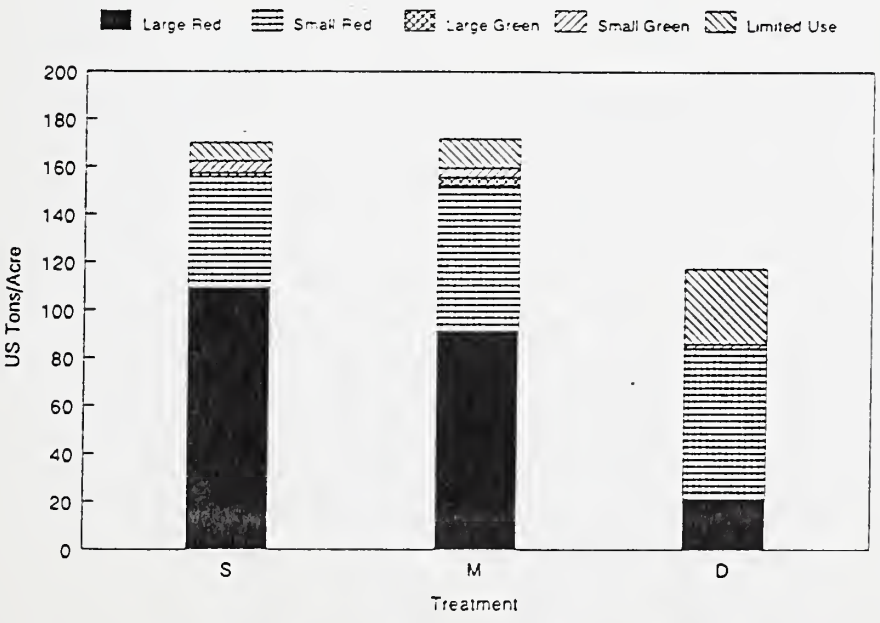


Figure 1. Broadview 1994 tomato yield components for the shallow (S), medium (M), and deep (D) groundwater areas.

LYSIMETER MEASUREMENTS OF EVAPOTRANSPIRATION IN MATURING GRAPES

R.M. Mead, D. Clark, L. Williams, and P. Biscay

OBJECTIVES: To use a computerized weighing lysimeter system for determination of evapotranspiration and crop coefficient (K_c) of drip irrigated grapes; to control in a real time feedback mode surface and subsurface drip systems at several evapotranspiration rates in the research site surrounding the lysimeter; to produce a set of crop coefficient functions for years two through six for use with CIMIS to schedule irrigation of grapes in the San Joaquin Valley.

PROCEDURES: The lysimeter, including the water in the tanks, was weighed hourly to determine the evapotranspiration (ET_c) of the two grapevines; the mass change was compared to a threshold mass of 96 kg (8 kg 1 mm ET_c) and after 96 kg of mass loss the lysimeter was irrigated until the threshold mass was met. At midnight each day, the water tanks were refilled to a pre-set level; the volume of water was measured with an electronic flowmeter and the lysimeter mass was used as the baseline mass for the next day. Daily crop coefficients (K_c) were calculated by taking the ratio of ET_c/ET_o where ET_o is reference evapotranspiration. Reference crop ET (ET_o) was calculated from data collected at a CIMIS weather station located at the Kearney Ag Center, approximately 325 m from the Thompson Seedless vineyard used in the study. Soil water content was measured with a Troxler Model 3332 Depth Moisture Gauge (neutron probe). Daily sensor outputs from the lysimeter were transmitted via telecommunication to the WMRL microcomputer and basic data were stored on a hard disk and backed up on high density floppy disks.

RESULTS: Table 1 shows monthly summaries of rainfall, lysimeter ET_c, the reference evapotranspiration (ET_o), the lysimeter K_c, the actual vine K_c, and the number of lysimeter irrigations. As discussed in previous reports, the K_c tracks evapotranspiration and hence its accuracy in predicting ET_c is limited to ± 10%, especially on a daily basis. Each vine used approximately 6612 L of water. Reference ET_o was 1244 mm. There were 714 irrigations, totaling 1428 mm of applied water and 265 mm of rainfall. No drainage was collected from the lysimeter. The two vines in the lysimeter grew to a size approximately equal to the size of the vines in the surrounding vineyard.

FUTURE PLANS: This experiment will be continued until the grape vines reach a fully mature stage.

Table 1. Monthly totals of rainfall, grapevine ET_c (lysimeter), reference ET (Et_o, CIMIS), lysimeter and grapevine K_c's, and number of irrigations.

Month	Rain (mm)	ET_c Lysimeter (mm)	CIMIS(ET_o) (mm)	Lysimeter K_c	Actual K_c* (7.52 m^2/vine)	# of Lysimeter Irrigations
Jan	33	15	31	0.48	0	0
Feb	44	25	47	0.53	0	0
March	16	64	91	0.70	0	0
April	24	87	129	0.67	0.36	6
May	20	191	161	1.19	0.64	85
June	1	283	213	1.33	0.71	142
July	1	328	201	1.63	0.87	206
Aug	1	301	159	1.89	1.01	151
Sept	25	207	113	1.83	0.98	96
Oct	21	115	64	1.80	0.96	28
Nov	42	24	26	0.92	0.49	0
Dec	37	13	9	1.44	0.77	0
Total	265	1653	1244	NA	NA	714

*Based on vine to vine spacing in field.

LYSIMETER MEASUREMENTS OF EVAPOTRANSPIRATION IN MATURING PEACH TREES

R.M. Mead, D. Clark, and S. Johnson

OBJECTIVES: To use a computerized weighing lysimeter system for determination of evapotranspiration of maturing peach trees and to control micro-irrigation systems in a real time feedback mode at several evapotranspiration rates in the research site surrounding the lysimeter. To produce a set of crop coefficient functions for years two through six for use with CIMIS to schedule irrigation of peaches in the San Joaquin Valley.

PROCEDURES: A lysimeter with dimensions of 2 m wide by 4 m long by 1.5 deep, containes two peach trees planted 2 m apart and centrally spaced. The lysimeter (including the water in its irrigation tanks) was weighed hourly to determine the evapotranspiration (ET_c) of the two trees; the mass loss of the lysimeter was compared to a threshold mass of 96 kg (8 kg = 1 mm ET_c per tree), and after 12 mm (96 kg) of ET was measured, the lysimeter was irrigated until the threshold mass was met. At midnight the water tanks were refilled to a pre-set level; the flow of water was measured electronically with a flowmeter and the new lysimeter mass was used as the baseline mass for the next day. Daily outputs from the lysimeters were transmitted automatically via telecommunication to the WMRL microcomputer and basic data were stored on a hard disk and backed up on high density floppy disks.

RESULTS: Table 1 shows monthly summaries of rainfall, lysimeter ET_c, grass reference ET_c (CIMIS), the lysimeter and actual tree crop coefficients (K_c's), and the number of lysimeter irrigations. Tree crop coefficients were established by dividing ETc by ETo on a summed monthly basis. As discussed in previous reports the K_c tracks evapotranspiration and hence its accuracy in predicting ET_c is limited to ± 10%, especially on a daily basis. Each tree used approximately 8860 L of water. Reference ET_c was 1244 mm. There were 163 irrigations, totaling 1956 mm of applied water and 260 mm of rainfall. No drainage was collected from the lysimeter. The two trees in the lysimeter grew to a size approximately equal to the size of the trees in the surrounding orchard.

FUTURE PLANS: This experiment reached its conclusion in the 1994 season. A Manuscript will be prepared.

Table 1. Monthly totals of rainfall, peach tree ET_c (lysimeter), reference ET (Et_o, CIMIS) lysimeter and peach tree K_c's, and number of irrigations.

Month	Rain (mm)	ET_c Lysimeter (mm)	CIMIS(ET_o) (mm)	Lysimeter K_c	Actual K_c* (8.91 m^2 /tree)	# of Lysimeter Irrigations
Jan	33	NA	31	NA	NA	0
Feb	44	NA	47	NA	NA	0
March	16	NA	91	NA	NA	0
April	24	156	129	1.21	0.54	3
May	21	237	161	1.47	0.66	19
June	0	414	213	1.94	0.87	34
July	0	496	201	2.47	1.11	42
Aug	3	451	159	2.84	1.27	37
Sept	25	276	113	2.44	1.10	21
Oct	19	155	64	2.42	1.09	7
Nov	39	22	26	0.85	0.38	0
Dec	36	8	9	0.89	0.40	0
Total	260	2215	1244	NA		163

*Based on tree to tree spacing in the field.

EVALUATING THE SENTEK ENVIROSCAN RT5 CAPACITANCE PROBE: LABORATORY CALIBRATION

R.M. Mead, J.E. Ayars, and J. Liu

OBJECTIVES: To calibrate the Sentek EnviroScan capacitance soil water monitoring system in various soil textures, densities and moisture regimes.

PROCEDURES: A special calibration apparatus constructed of 30 cm (12 in) diameter PVC pipe was segmented into 4 distinct chambers. Each chamber was 30 cm (12 in.) in height. The chambers were stacked on top of one another to produce a vertical column, such that a 49 mm (2 in) diameter PVC access tube could be vertically inserted down the center of the chamber-column array. The PVC access tube accommodated the Sentek EnviroScan RT5 probe with attached sensors. Each chamber was horizontally separated by one sheet of 6 mm (0.25 mm) thick Plexiglas. Three different soil types were chosen for calibration purposes: coarse sand (100% sand), a sandy loam (59% sand, 22% silt, 19% clay) and a clay (16% sand, 35% silt, 49% clay). The soils were hand packed around the PVC access tube to various densities. The sand was packed to a bulk density of 1.3 g/cm^3. Due to the more pliable nature of the sandy loam soil, bulk densities of 1.3 and 1.5 g/cm^3 were created. The clay soil density was established at 1.01 g/cm^3. (All soil bulk densities were calculated using a soil bulk density brass ring sampler during soil sampling). Various moisture regimes were introduced in the chamber by mixing the soil thoroughly at the desired moisture content prior to packing. The volumetric moisture content for sand ranged from 3 to 15%, from 4 to 35% for the sandy loam and from 13 to 54% for the clay soil. With the exception of the sand, the sandy loam and clay soils were left undisturbed for 24 hours after densities and specific soil moisture were obtained. After 24 hours, raw sensor readings (frequency output) were taken from the 4 Sentek sensors nearest to the center of each chamber access tube area. Due to the high infiltration nature of the sand, Sentek readings and soil samples were taken immediately after density packing. All readings were taken via the Sentek logger/computer interface setup. Immediately after readings were taken, soil samples were taken with a 135 cm^3 bulk density sampler within 2.5 cm (1 in.) of the specific sensor inside each chamber. Soils were weighed immediately and placed in a drying oven at 105°C for 48 hours then weighed dry for volumetric water content analysis.

RESULTS: Using an average of 40 samples per soil type and density, there was good correlation between the Universal Frequency vs. true volumetric water content. Universal Frequency is defined as $UF = Fa - F / Fa - Fw$, where Fa represents "air" normalization readings, Fw represents "water" normalization readings, and F represents actual raw field count readings within the access tube in the soil. All derived linear equations were similar in nature and had R values above 0.95 (Table 1). Combining all soil types and densities also provided a good linear calibration equation which encompassed a wide range of volumetric moisture contents (Fig. 1)

Table 1. Linear equations with R values derived from plotting true volumetric soil moisture vs Universal Frequency out put of the Sentek Enviroscan RT5 system.

Soil Type	Density (g/cm^3)	Linear equation	R Values
Sand	1.30	0.017x + 0.2681	0.987
Sandy loam	1.30	0.0129x + 0.3258	0.965
Sandy loam	1.50	0.0125x + 0.3724	0.987
Clay	1.01	0.0122x + 0.4157	0.979
Combined soils	1.28	0.0139x + 0.3262	0.971

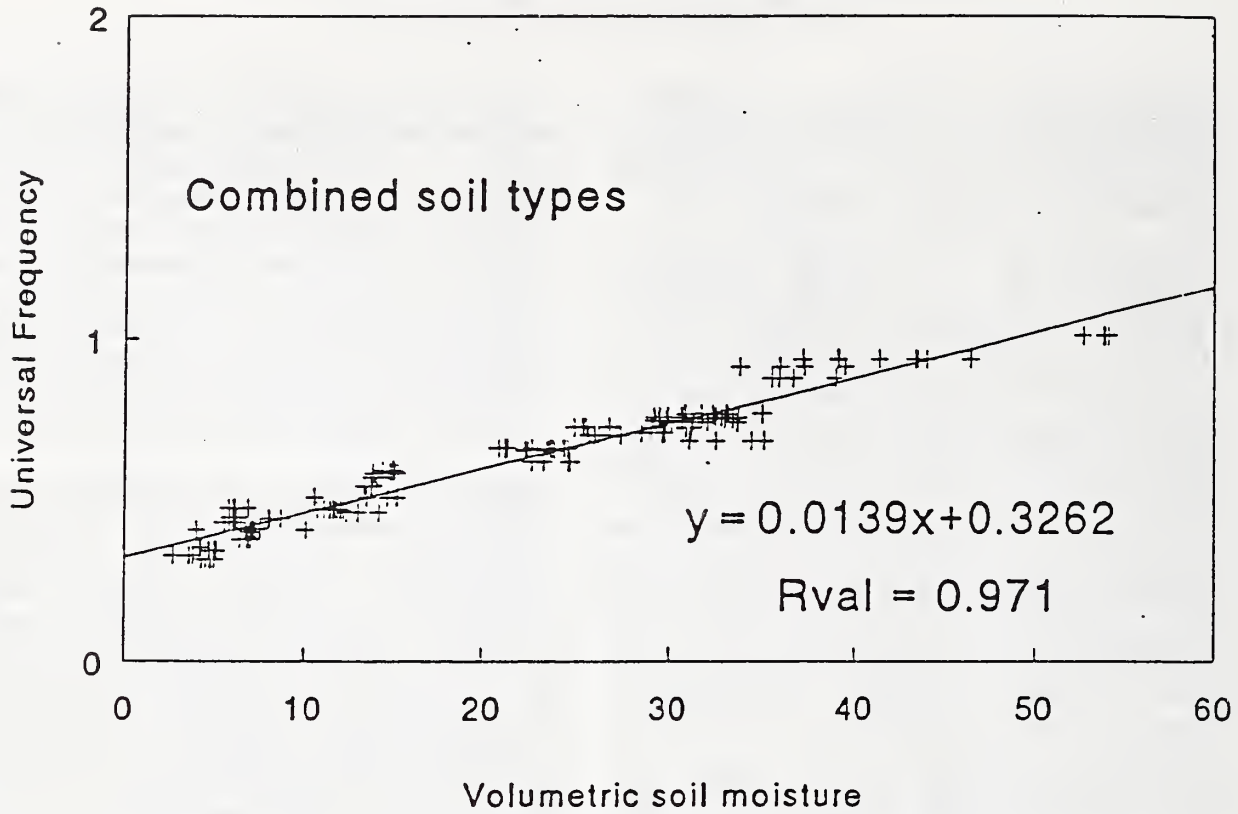


Figure 1. Calibration equation of sand, sandy loam and clay at various densities using the Sentek EnviroScan RT5 capacitance probe.

EVALUATING THE SENTEK ENVIROSCAN RT5 CAPACITANCE PROBE: FIELD ANALYSIS

R.M. Mead, J.E. Ayars, J. Liu, and R. Soppe

OBJECTIVES: To evaluate the Sentek EnviroScan capacitance soil water monitoring system in a field situation, using differential placement depths of a subsurface drip system irrigating a winter broccoli crop.

PROCEDURES: Sentek probe tubes were installed at the WSFS lysimeter field during the growth cycle of a broccoli crop. Tubes were specifically placed in the middle of 1.5 m (60 in.) beds, perpendicular to and adjacent to buried drip emitters. The three installed tubes were in the three main treatments of the field: drip laterals buried at 30, 45 and 60 cm below grade. Sentek sensors were installed on each probe at 10, 20, 30, 40, 50, 60, 80 and 90 cm below the soil surface. Data was automatically taken at one hour intervals and manually dumped four times during the 1994-1995 season. Irrigations (1 to 3 per day) were accomplished using a data logger clock connected to the pump manifold. A crop lysimeter in mid-field recorded hourly and daily ETc of the crop. Weather data was recorded at a weather station approximately 50 m southeast of the Sentek probe tube site. There were three main situations of pump down time, and numerous occurrences of precipitation during the broccoli growth cycle.

RESULTS: Irrigation induced fluctuations were observed in the 30 and 60 cm lateral depth plots, but were not observed as vividly in the 45 cm lateral depth plots. The 45 cm lateral depth plots did not display these fluctuations probably because the soil around the buried drip line has had time to settle since this "treatment" represents the initial subsurface drip lateral installed in 1984 (Fig 1). Another theory might be due to differences in installation techniques. The 45 cm treatment was installed using a trencher/backfill technique. The 30 and 60 cm treatments were shanked in using a tractor implement. The 30 and 60 cm treatments also showed fluctuations during irrigations most likely due to a scaring affect from the somewhat recent shanking installation of the drip system, whereby infiltration properties have been potentially hampered. Also, thermal induced fluctuations occurred in the top 30 cm of all treatments due primarily to proximity diurnal solar warming (Fig. 2 and 3).

FUTURE PLANS: More Sentek capacitance access tubes will be installed in the same sensor location as above, and other tubes will be installed in-between emitter locations. Hence, upon installing the additional system, better modeling information will be obtained using capacitance sensors both at emitter proximity and between emitters. Additional matric potential sensors will also be distributed away from emitters to obtain similar information on water distribution in the three treatments of the subsurface drip irrigated field.

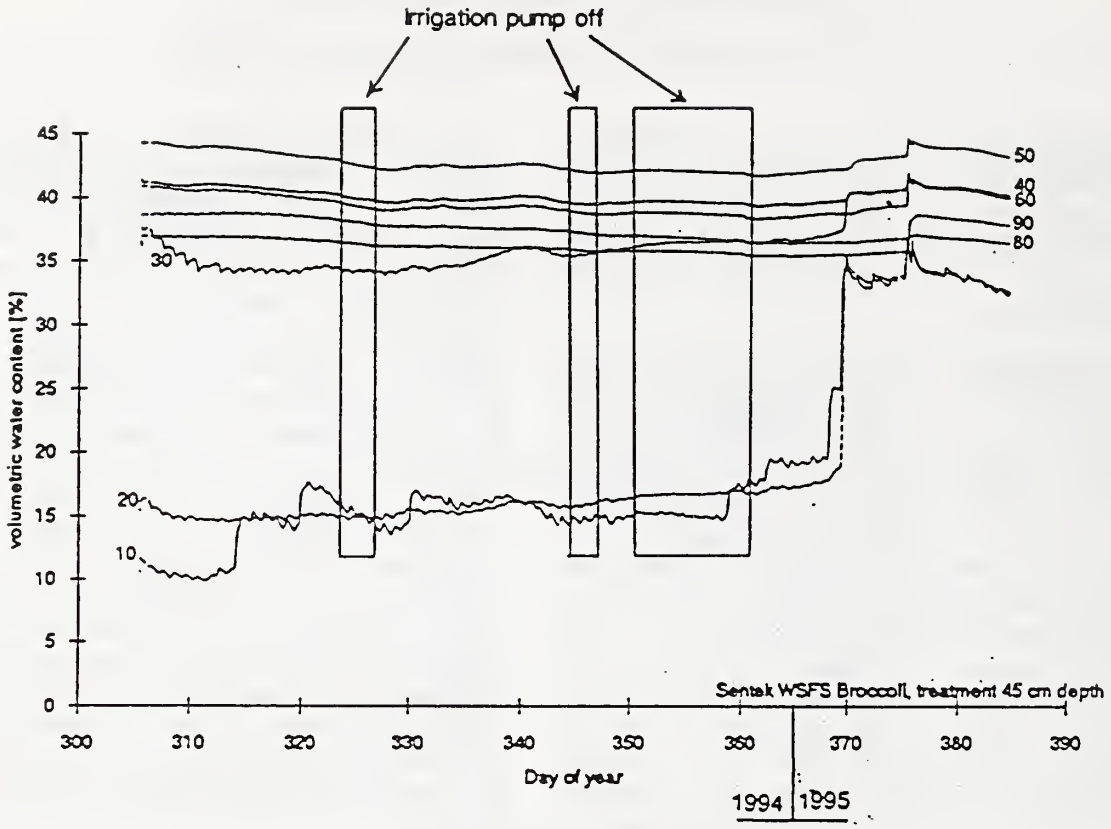


Figure 1. Sentek volumetric water content (%) during the growing season of broccoli in a plot with drip aterals buried 45 cm deep.

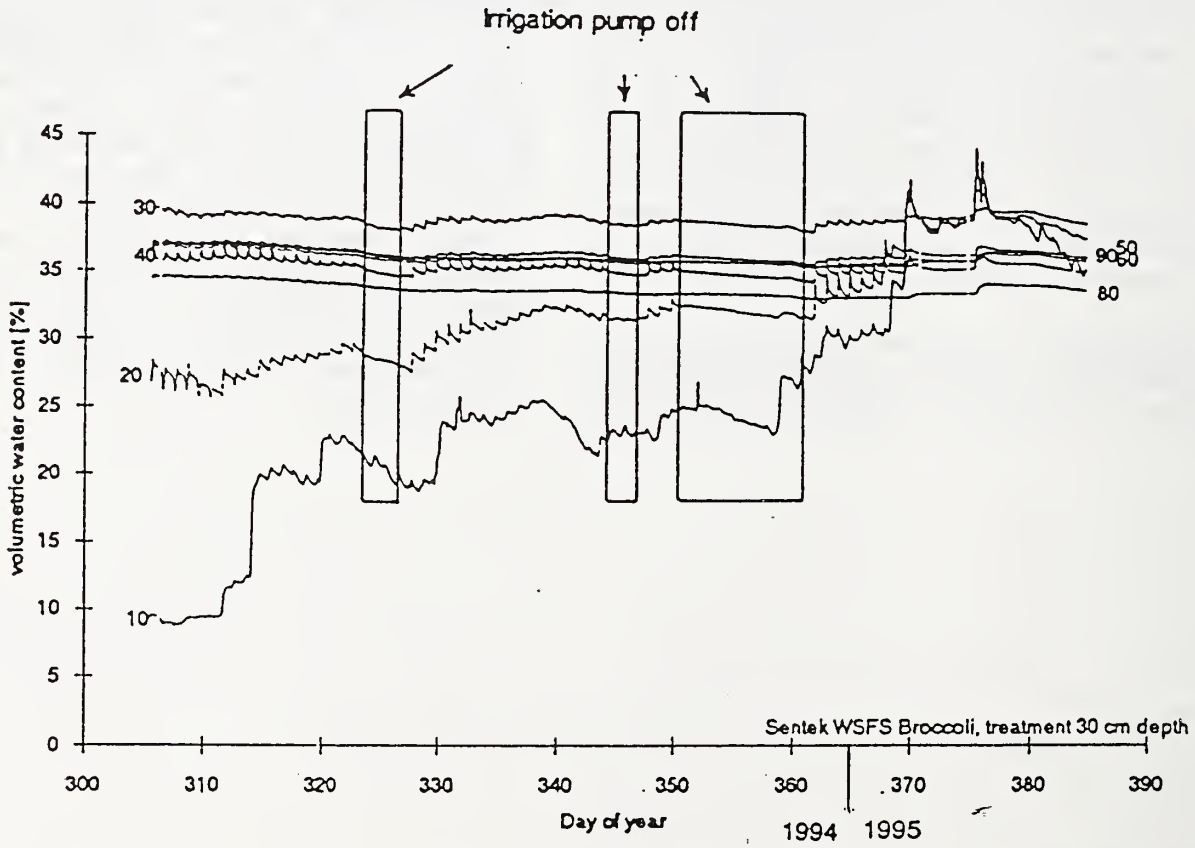


Figure 2. Sentek volumetric water content (%) during the growing season of broccoli in a plot with drip laterals buried 30 cm deep.

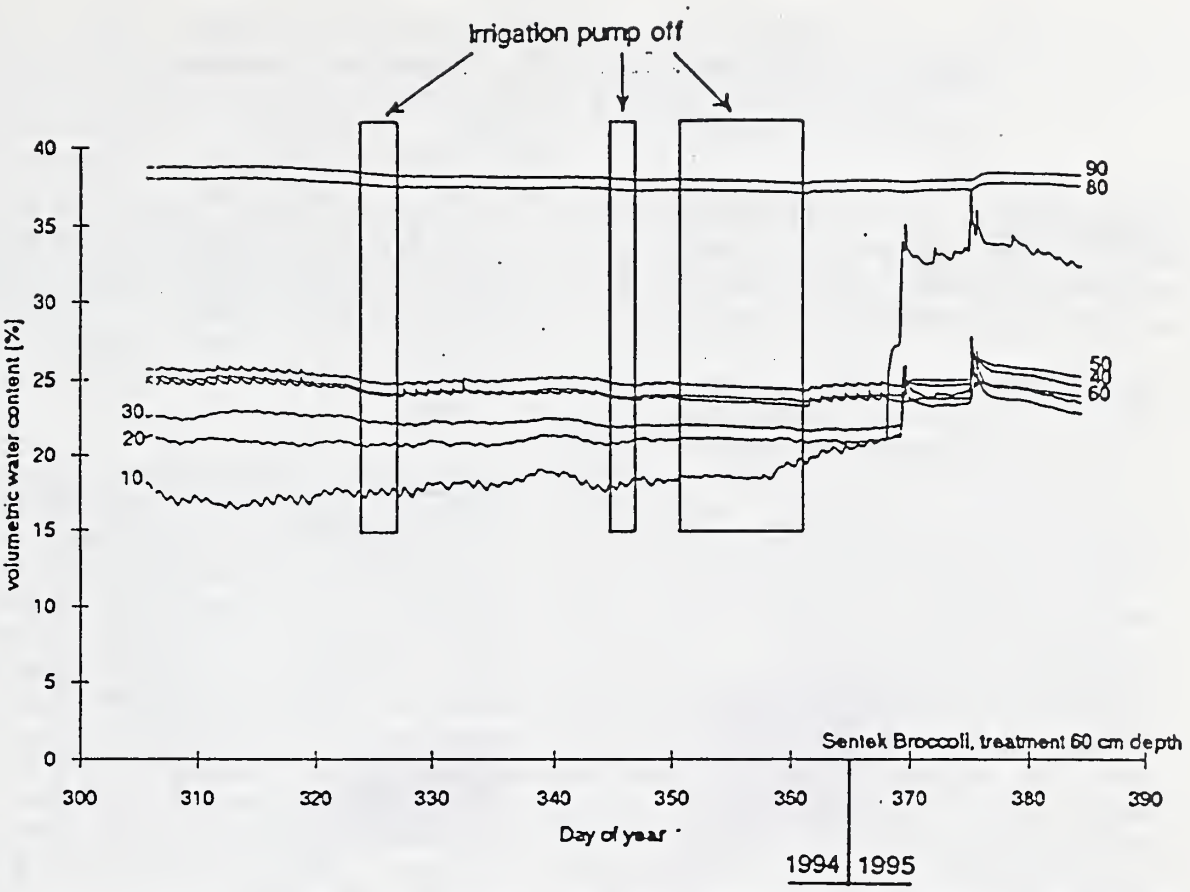


Figure 3. Sentek volumetric water content (%) during the growing season of broccoli in a plot with drip laterals buried 60 cm deep.

EVALUATING THE SENTEK ENVIROSCAN RT5 CAPACITANCE PROBE: INITIAL SALINITY CALIBRATION

R.M. Mead, J.E. Ayars, and J. Liu

OBJECTIVES: To calibrate the Sentek EnviroScan capacitance soil water monitoring system in various soil salinities and moisture contents.

PROCEDURES: A sandy loam soil was selected for specific salinization using waters having electrical conductivity of 0.5, 6.0, 12.0 and 38.0 dS/m, respectively. The saline water was artificially created using equal amounts of NaCl and $CaCl_2$ salt in the solution. Wet, semi-wet and dry calibration runs were performed to establish: (a) how salinity affects capacitance readings, and (b) if salinized soil affects capacitance readings at various moisture contents. The wet salinization calibration run consisted of the sandy loam soil being thoroughly wetted with specific saline waters to a point at or near field capacity. The semi-wet and dry saline calibration runs were performed by pouring one pore volume of 30 dS/m solution through the sandy loam soil, then allowing the soil to drain and air dry to the desired moisture content. The salinized soil was then hand packed in the calibration chamber for capacitance probe analysis.

RESULTS: The wet saline soil calibration displayed capacitance volumetric moisture levels of higher value than true volumetric water content. The more saline the soil became, the more the capacitance volumetric water readings were skewed higher relative to true volumetric moisture. When using the same saline water in the normalization setup (water basket) which salinized the wet soil, capacitance volumetric moisture levels were lowered. However, the more saline the water, the less this lowering effect occurred (Fig. 1).

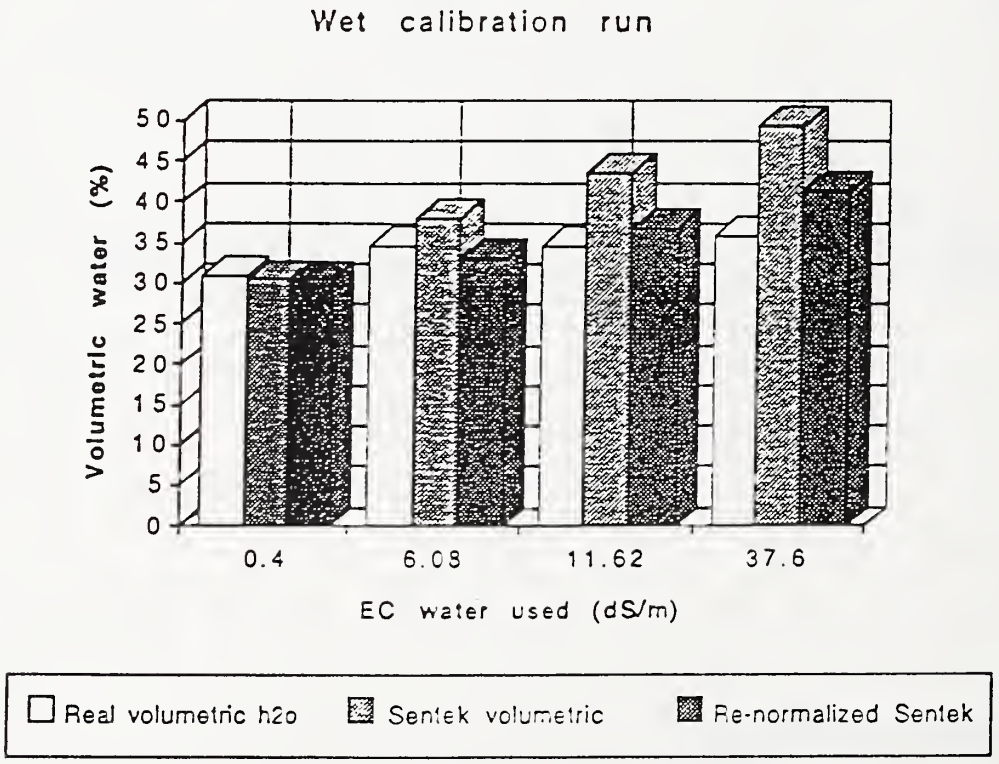


Figure 1. Volumetric water content recorded by Sentek capacitance probe using fresh and saline water during normalization process vs true soil moisture content.

Using saline waters of 30 dS/m demonstrated that drier moisture levels of a salinized soil give rise to proportionally higher moisture readings. Hence, decreasing soil moisture in iso-saline soils has an inverse relationship to skewing capacitance volumetric readings (Fig. 2). Apparently salts in the saline soil upon drying, make increased physical anomalies to the electric field generated by measuring the soil dielectric constant. This presents a calibration dilemma for soils having high salinity.

FUTURE PLANS: Two more saline calibration runs (5 and 15 dS/m) will be completed in 1995 to establish at which salinity level capacitance readings begin to be affected by different moisture regimes.

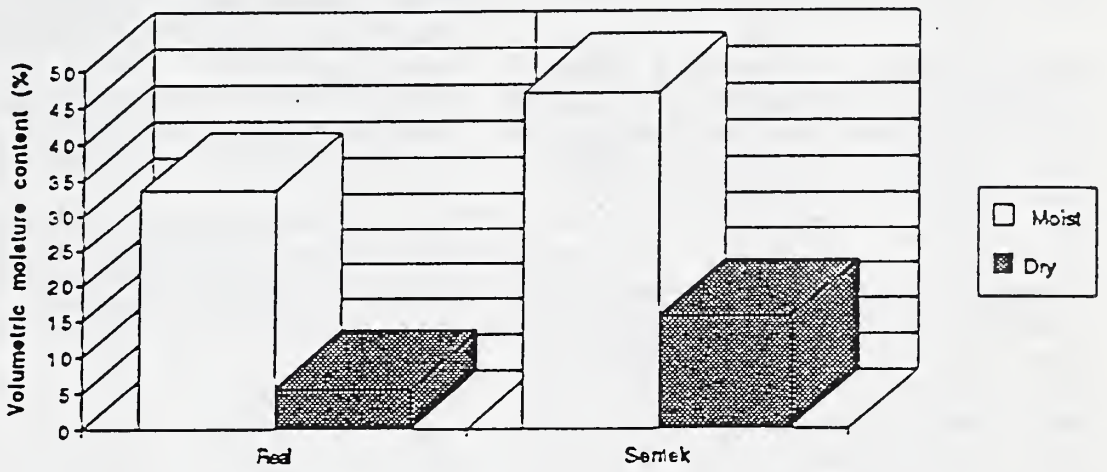


Figure 2. Volumetric moisture content comparing real vs Sentek values with two different moisture regimes at irrigation water salinity levels of 30 dS/m.

A COMPARISON OF AUTOMATED ATMOMETERS TO OTHER ESTIMATES OF EVAPOTRANSPIRATION

R. Mead, D. Clark, C. Hawk, A. Neverez, J. Altenhofen, H. Hetzel

OBJECTIVES: To evaluate automated atmometer instrumentation (ETgage Company, Loveland, CO.) and compare the values to crop and grass lysimeters, CIMIS ETo estimations and automated evaporation pan data.

PROCEDURES: Automated ETgage atmometers were installed at the U.C. West Side Field Station, Five Points and at the USDA Irrigated Desert Research Station, in Brawley, CA. At the WSFS, the first ETgage (ETg#1), was installed on February 16, positioned north of the grass lysimeter, whereby the top of the device was 1 m above the grass canopy of the grass lysimeter. This Etgage used a style #30 canvas cover placed over the ceramic evaporative cup. On April 15, ETg#2, was installed within 30 cm west of ETg#1 and at the identical height. This Etgage atmometer contained style #54 canvas cover. Hence, at this site, the two ETgage devices with different evaporative surfaces would be in proximity to a reference grass lysimeter (ETr), a CIMIS station (ETo), and an evaporation pan (Ep). Later in the year, the newest device by ETgage company, the X-7, was installed using the water source and electronic circuitry from ETgage #1. The newer device was installed at 2.5 cm above the grass of the grass lysimeter southwest of ETg #1 and #2.

At the Irrigated Desert Research Station (Brawley), an ETgage automated atmometer was installed on April 8, at 1 m height north of a 3 x 3 m alfalfa lysimeter, irrigated by subsurface drip. The ceramic evaporative cup cover on this Etgage atmometer was style #54 canvas cover. A CIMIS weather station (ETo) and an automated evaporation pan (Ep) were located approximately 250 m northeast of the lysimeter area.

RESULTS: Overall, the ETgage atmometers responded marginally well in 1994. At the WSFS, ETg#1 had linear regression values of 0.87 and 0.87 plotted against ETr (grass lysimeter) and CIMIS ETo, respectively. The ETg#2 had linear regression values of 0.83 and 0.82 for the same parameters. When assessed by monthly totals, the highest ETg/ETr ratios occurred in April for ETg#1 and in October for ETg#2 (Table 1). For ETg/ETo ratios, ETg#1 had the best relationship in July while ETg#2 was in October. Yearly linear regressions with evaporation pans were poor. Ep-open vs. ETg linear regression values were 0.56 and 0.71 for ETg#1 and ETg#2, respectively. Problems with the closed evaporation pan provided inconsistent results with either ETgage atmometer. At the year's end, the X-7 had ETr and ETo vs. ETg regression values of 0.81 and 0.88, respectively.

Table 1. ETg/ET parameter ratios at the WSFS in 1994, using the grass lysimeter as ETr and CIMIS data as ETo estimation.

Month	ETg#1/ETr	ETg#1/ETo	ETg#2/ETr	ETg#2/ETo
Jan	0	0	0	0
Feb	0.33	0.41	0	0
Mar	0.83	0.77	0	0
Apr	0.97*	0.70	0.48	0.35
May	0.71	0.72	0.77	0.77
June	0.79	0.68	0.81	0.70
July	1.14	0.79*	1.27	0.88
Aug	0.43	0.29	0.5	0.34
Sept	0.026	0.027	0.8	0.81
Oct	0.09	0.09	0.97*	0.98*
Nov	0.29	0.25	0.44	0.38
Dec	0.21	0.2	0.5	0.47

* Represents the best ratio of that particular parameter for the year.

At the Irrigated Desert Research Station (Brawley), ETg/ETr ratios fluctuated. This was probably due to varying crop canopy densities from 7 alfalfa harvest cuttings throughout the year (Table 2).

However, ETg/ETo ratios were not better. This could be explained due to the poor management of the local weather station, primarily flooding of the grass area for disposal of the station's excess irrigation water.

Future plans: The ETgage X-7 at the WSFS will still be investigated for ET estimations. Evaporation pan analysis will be more thoroughly assessed. The ETgage at Brawley will be monitored until the project's end.

Table 2. ETg/ETc parameter ratios at the Irrigated Desert Research Station at Brawley in 1994, using the alfalfa lysimeter as ETc and CIMIS data as an ETo estimation.

Month	ETg/ETc	ETg/ETo
Jan	0	0
Feb	0	0
Mar	0	0
Apr	0	0
May	0.74	0.78
June	0.97*	1.13
July	1.04	1.2
Aug	0.93	0.95*
Sept	0.66	0.57
Oct	0.51	0.44
Nov	1.15	1.05*
Dec	1.06	1.13

* Represents the best ratio of that particular parameter for the year.

NITROGEN MANAGEMENT OF COTTON UNDER SUBSURFACE DRIP IRRIGATION - IDENTIFICATION OF CRITICAL NITROGEN LEVELS: I. OPERATIONAL PROCEDURES

R.B. Hutmacher, S.S. Vail, M.S. Peters, C.A. Hawk, M. Keeley, T. Pflaum, D.A. Clark,

OBJECTIVES: This drip irrigation experiment is part of a three to five year cooperative project with University of California Extension staff. The long-term goal is to identify growth-stage-specific relationships of plant and soil nitrogen under specific management practices to specific physiological processes, growth and yield limitations. Other projects associated with this drip project are investigating methods to split fertilizer applications using surface irrigation rather than drip irrigation.

The subsurface drip system is being used in this portion of the study to deliver precise amounts of nitrogen fertilizer over time and to identify plant responses to different severities and timing of nitrogen deficits.

PROCEDURES: *Irrigation System.* Cotton (var. "Maxxa") was planted on JD 106 (May 10, 1994). Mepiquat chloride (PIX) was applied uniformly to all plots at a rate of 0.9 L ha^{-1} in July. The drip laterals were spaced 1.52 m apart under alternate furrows and 45 cm below the average soil surface. Drip emitters (turbulent-flow, in-line design) were spaced 0.91 m apart along the laterals, and had a nominal flow of 2 L h^{-1} at 120 to 140 kPa operating pressure. Each plot consisted of 12 rows spaced 0.76 m apart and 9.3 m in length. The SDI system was programmed to replace 100% of the daily evapotranspiration (ET_c) daily, with the system operated at a frequency corresponding to every 2 mm of accumulated ET_c. The ET_c was calculated using a K_c developed earlier on-site in conjunction with the grass reference evapotranspiraton (ET_o) determined at the adjacent K_c weather station.

Plant water status resulting from irrigation treatments was monitored using a crop water stress index (CWSI) approach with an infrared thermometer and hand-held psychrometer. Measurements of crop water status were made at one week intervals throughout the season.

An average of 516 mm of irrigation water was applied to all treatments during the growing season. Approximately 140 mm of water was applied by sprinkler (pre-plant). Calculated crop evapotranspiration (including measured soil water depletion) averaged 725 mm for the growing season, and ranged from a low of 678 mm in the no nitrogen treatment to over 770 mm in a high nitrogen treatment (see below for treatment descriptions).

N Fertilizer Treatments. This year, the six fertilizer treatments included one control with no N added (T1), and combinations of patterns of N application (linear T8 and T9) versus growth-stage and uptake rate-dependent (T2, T3, T4). Target amounts of applied N were 60 (2T), 120 (T3), 180 (T4, 8, 9) kg N ha^{-1}. Actual N amounts applied were 67 kg N ha^{-1} (T2), 133 kg N ha^{-1} (T3), 200 kg N ha^{-1} (T4, 9) and 251 kg N ha^{-1} (T8). Nitrogen applications in T8 were all made between day 165 and 207, while applications in T9 were made between day 193 and 221. All other treatments commenced N applications on day 165 and ended day 228. All treatments were replicated four times and N was applied using a venturi-type injector. Phosphoric acid and calcium ammonium nitrate were used to apply phosphorus and nitrogen, respectively. A total of 81 kg P ha^{-1} was applied uniformly to all treatments.

Soil Sampling. Soil samples were collected JD 164-166 (June 13-15) in 22.5 cm increments to 90 cm and 30 cm increments from 90 to 150 cm to a depth of 1.5 m to establish initial soil nutrient and salinity levels in each block of the field. Additional samples were collected to a depth of 3 m on JD 334-335 (Nov. 30-Dec. 1), post-harvest. All samples will be analyzed for soil water content, electrical conductivity, pH, NO_3-

N, PO_4-P, K, Total N, Cl, Ca, Mg, and Na.

Plant Sampling – Nutrients, Growth, Yield. Plant Sampling - Nutrients, Growth, Yield. Petiole samples from the most recent fully-expanded leaves were collected weekly and analyzed for NO_3-N, PO_4-P, and K. Above-ground plant samples were collected five times during the growing season to identify above-ground nutrient uptake based upon the average tissue nutrient concentrations and dry matter sampling of component plant parts. Main stem and sympodial leaves at different positions within the canopy were sampled at intervals through the season and analyzed for gas exchange rates, total-N, and incident radiation, as well as conductance and transpiration rates.

Plant growth and development were monitored as plant height, node counts, nodes above white bloom, boll counts and position, plant leaf area, and dry matter partitioning. Plots were machine harvested on JD 312 with a modified commercial spindle picker and seed cotton yields were determined on two rows per plot. Gin turnout was determined at the USDA-ARS Cotton Laboratory in Shafter, CA.

RESULTS AND DISCUSSION: See accompanying reports for details of results on plant gas exchange, water relations, petiole nutrient levels and growth and yield responses.

NITROGEN MANAGEMENT OF COTTON UNDER SUBSURFACE DRIP IRRIGATION: II. LEAF GAS EXCHANGE

R.B. Hutmacher, S.S. Vail,
M.S. Peters, C.A. Hawk, D.A. Clark

OBJECTIVES: This subsurface drip irrigation experiment is part of a series of three to five year cooperative projects with the University of CA Cooperative Extension with the long-term goal of identifying growth-stage specific levels of nitrogen (N) and their relationships to specific physiological functions, growth and yield limitations. For more details, see report entitled: "Nitrogen Management of Cotton under Subsurface Drip Irrigation - Identification of Critical N Levels: Operational Procedures" elsewhere in this volume.

PROCEDURES: Leaf abaxial and adaxial resistances and transpiration rates were monitored at 7 day intervals at specific leaf positions using a Li-Cor 1600 series steady-state porometer. Incident photosynthetic photon flux density (PPFD) was monitored for each leaf monitored, and only leaves with PPFD levels in excess of 1200 μmoles m^{-2} s^{-1} were used in this analysis.

Single leaf photosynthetic rates were determined at 7 day intervals using an ADC infrared gas analyzer and Parkinson leaf chamber in the flow through mode with a constant flow rate of 0.6 L min^{-1}. The third, fifth or sixth, and eighth or ninth leaf from the uppermost node were monitored in order to determine the relative sensitivity of leaves of different stages of maturity and different ages to the imposed N fertilizer treatments. For the sake of brevity, only results collected from the first fully-expanded recently mature leaf (fifth or sixth leaf from the uppermost node) will be discussed. However, general findings for the fifth or sixth leaf also apply to the other leaf ages. For more details of plant responses, see other reports in this series. For other details see report entitled: "Nitrogen Management of Cotton under Subsurface Drip Irrigation - Identification of Critical N Levels: Operational Procedures" elsewhere in this volume.

RESULTS / DISCUSSION: As observed during 1993, on any measurement dates, leaf conductances were not significantly affected by any nitrogen treatment (data not shown). Prior studies in Arizona suggest that severe N deficits result in reduced leaf conductance (similar to a water deficit response), but petiole NO_3-N levels in those Arizona studies were significantly lower than in the no N and low N treatments in the current study (see data presented elsewhere in this volume). Leaf age was much more a determinant of leaf conductance, with the highest and most variable conductance in the youngest leaves (third node from the top of the plant) and lowest in the older leaves at the eighth or ninth node from the top.

Single leaf net photosynthetic rates were much more variable in 1994 than measured in 1992 or 1993 (Fig. 1 through 4). We believe this to be due to the significantly greater insect and mite problems in 1994, which caused some moderate to severe foliar damage in some field replications. Although the variability in measurements and late planting date complicate the data interpretation, photosynthetic rates were significantly reduced in the no N (treatment T1) and low N (T2) treatments starting in August in T1 and late August in treatment T2, particularly in the youngest (Fig. 1) and oldest (Fig. 3) leaves monitored. There were no significant differences between leaf photosynthetic rates between the plants in the moderate (120 kg N ha^{-1}) treatment (T3) and the high N (180 kg N ha^{-1}) treatments.

If reductions in photosynthetic capacity occur relatively late in the season (when bolls are relatively mature and carbohydrate demands are low), the affects on lint yield would be expected to be minimal. If, however, the reductions in photosynthetic capacity occur with a late boll set, reduced photosynthetic capacity should be more important in being a partial cause of

reduced yields. The relative pattern of within-season reductions in leaf photosynthetic capacity occuring during leaf aging and boll filling are shown in Figure 4, with similar patterns of change in leaves from the third, sixth and ninth leaves from the uppermost node.

Data from the first two years of this study indicate that reduced N applications in the moderate N treatments did not reduce plant N levels sufficiently to influence net photosynthesis. The relative importance of stored soil N in providing N to avoid deficits in moderate N application treatments has not been established at the time of this report.

Photosynthetic rate reductions were not caused by reductions in leaf conductance, but rather were due to nonstomatal limitations, resulting in significantly lower net photosynthesis per unit leaf conductance in the no N treatment (data not shown) and low N treatments. This reduction was particularly accentuated during the period of rapid boll development.

Leaf Total N Status. Total N content of the most recent, fully-expanded leaves (expressed as percent N on a dry weight basis) was significantly lower in the treatment T1 (no N fertilizer) plants than in other treatments as early as day 198 (mid-July) (Figure 5). In comparison, leaf total N in treatment T2 (60 kg N ha^{-1} rate) was not significantly lower than in higher N treatments until mid- to late-August. Part of the reason for the relatively late timing of reductions in leaf N in the no N and low N treatments is the presence of residual soil N in the upper 60 cm of the soil profile and the late planting date (day 131).

Mid- to late-season reductions in leaf total N in treatment T1 and T2 are correlated with reductions in late-season leaf photosynthetic rates (Figures 1 through 4), and may be severe enough to reduce soluble protein and restrict photosynthetic rates, but this did not occur until very late in the growing season.

FUTURE PLANS: This study is planned to continue for at least two years after the 1994 season, with emphasis on continuing determination of specific relationships between petiole NO_3-N, leaf N and growth and gas exchange responses.

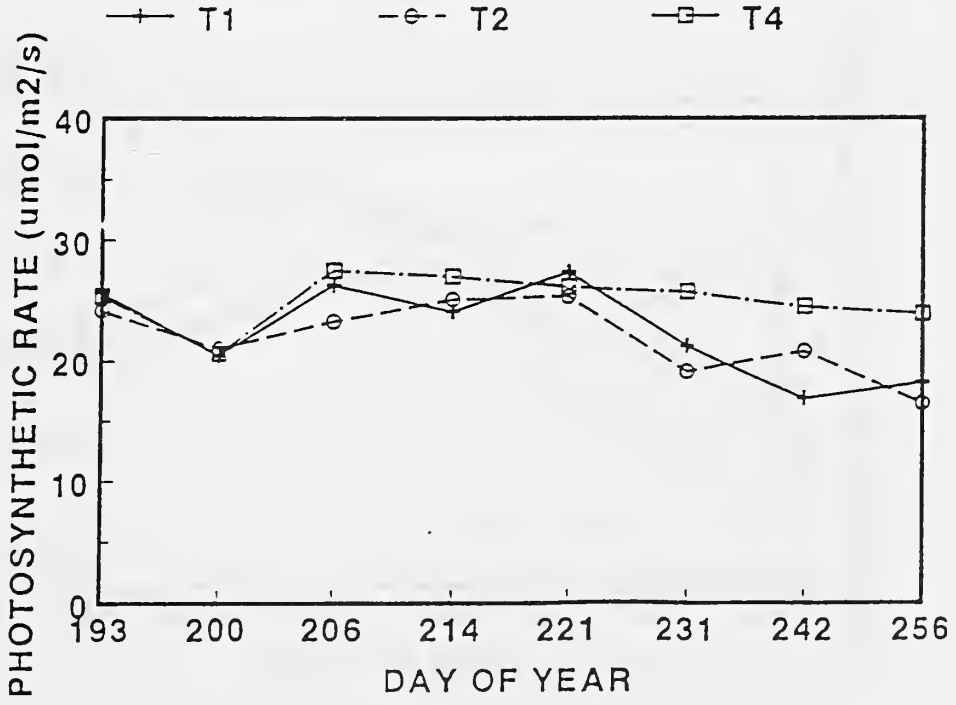


Figure 1. Leaf net photosynthetic rates for the third leaf from the uppermost node as a function of day of the year and nitrogen fertilizer treatment (treatments T1, T2 and T4 only). Data collected is from the 1994 cotton project at the West Side Research and Extension Center near Five Points, CA.

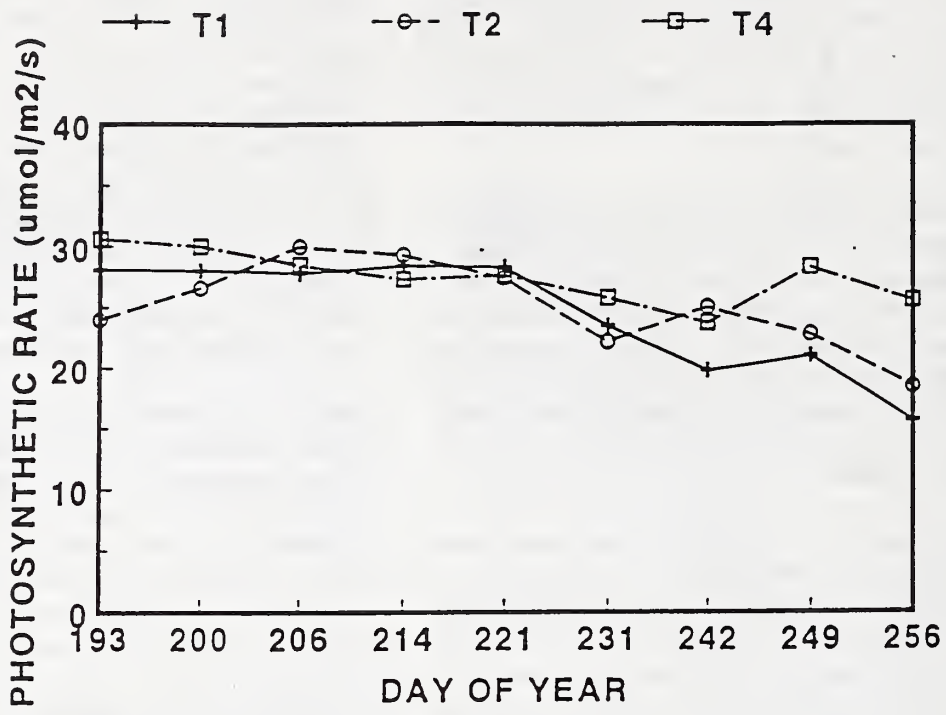


Figure 2. Leaf net photosynthetic rates for the sixth leaf from the uppermost node as a function of day of the year and nitrogen fertilizer treatment (treatments T1, T2 and T4 only). Data collected is from the 1994 cotton project at the West Side Research and Extension Center near Five Points, CA.

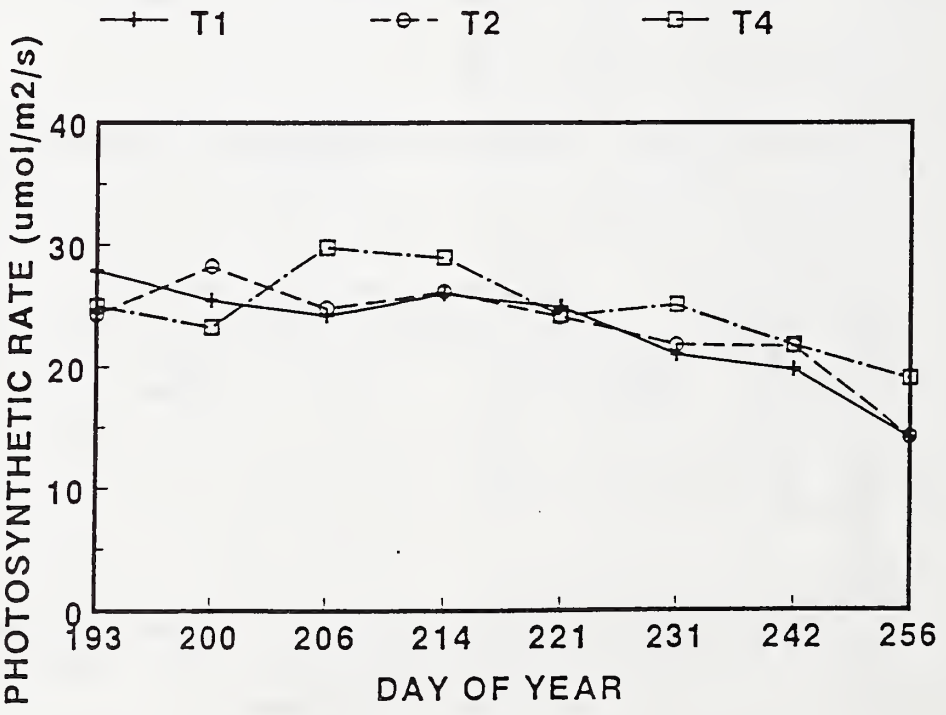


Figure 3. Leaf net photosynthetic rates for the ninth leaf from the uppermost node as a function of day of the year and nitrogen fertilizer treatment (treatments T1, T2 and T4 only). Data collected is from the 1994 cotton project at the West Side Research and Extension Center near Five Points, CA.

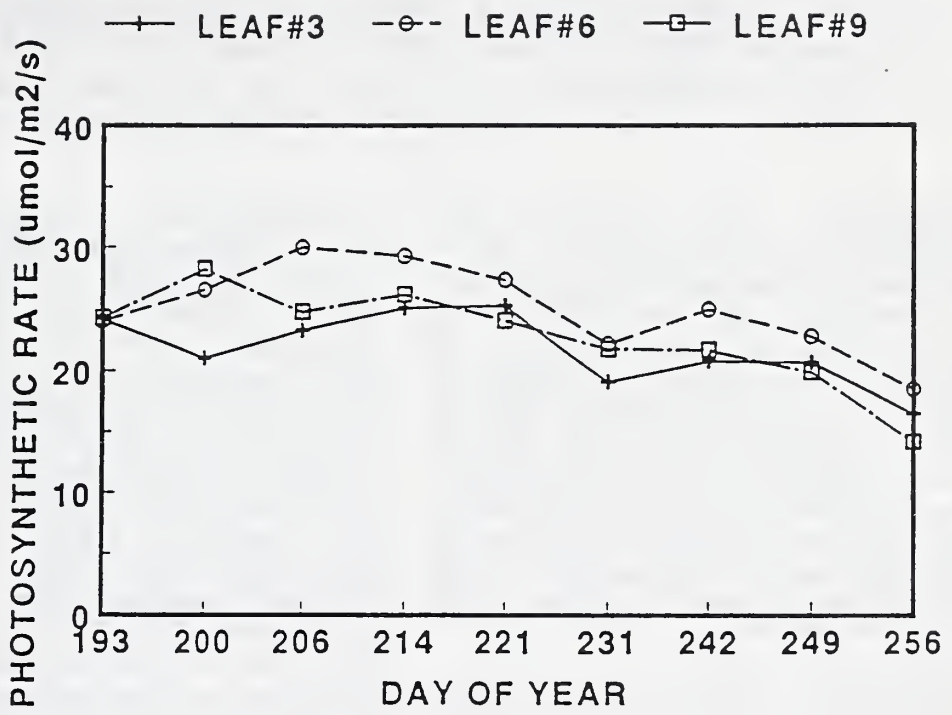


Figure 4. Leaf net photosynthetic rates for the third, sixth and ninth leaf from the uppermost node as a function of day of the year in fertilizer treatment T2. Data collected is from the 1994 cotton project at the West Side Research and Extension Center near Five Points, CA.

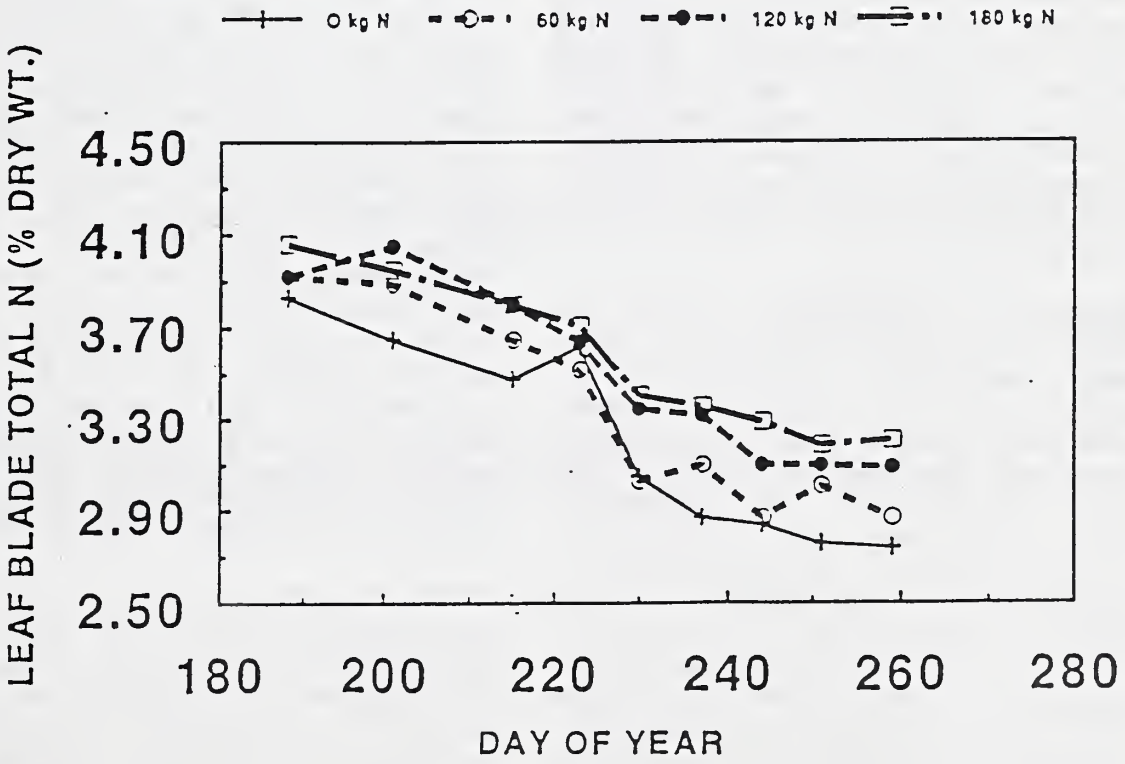


Figure 5. Leaf blade total N concentration (expressed as % on dry weight basis) as a function of fertilizer treatment and day of year in 1994 cotton project at the West Side Research and Extension Center near Five Points, CA.

NITROGEN MANAGEMENT OF COTTON UNDER SUBSURFACE DRIP IRRIGATION: III. PETIOLE NUTRIENT STATUS

R.B. Hutmacher, S.S. Vail. B. Weir, K.R. Davis, R. Vargas, M. Keeley, T.A. Kerby, T. Pflaum, M.S. Peters, C.A. Hawk, D.A. Clark

OBJECTIVES: This subsurface drip irrigation experiment is part of a series of three to five year cooperative projects with the University of CA Cooperative Extension with the long-term goal of identifying growth-stage specific levels of nitrogen (N) and their relationships to specific physiological functions, growth and yield limitations. For more details, see report entitled: "Nitrogen Management of Cotton under Subsurface Drip Irrigation - Identification of Critical N Levels: Operational Procedures" elsewhere in this volume.

PROCEDURES: Petiole samples were collected at 7 to 10 day intervals throughout the season and dried at 50 to 55 degrees C for a minimum of 48 hours prior to grinding and analysis. A minimum of 25 petiole samples were collected per treatment block from separate plants at the uppermost fully-expanded leaf node. For more details of plant responses, see other reports in this series. For other details see report entitled: "Nitrogen Management of Cotton under Subsurface Drip Irrigation - Identification of Critical N Levels: Operational Procedures" elsewhere in this volume.

RESULTS / DISCUSSION: The most significant reductions in petiole NO_3-N were consistently observed in the untreated control (no nitrogen treatment, treatment T1) and in the low nitrogen treatments (treatment T2) (Fig. 1a). Petiole NO_3-N levels were significantly higher in treatments T3, T4 than in T1, T2 during most of the season, with no significant differences between levels in T3 and T4 (120 kg N ha^{-1} versus 180 kg N ha^{-1}) (Figs. 1b, 1c). Since there were no pre-plant N comparison treatments in 1994 (omitted due to problems with the field and size of plots available), it was not possible to evaluate the effects of pre-plant N applications as in prior years of this study. Plans are to include the pre-plant N comparison as part of the 1995 continuing study. Treatments T8 and T9, with N applications made during short periods beginning in early and mid-season, respectively, did not exhibit significantly higher petiole NO_3-N until late in the season (Fig. 1d). Petiole NO_3-N levels in T9 were significantly reduced through early July as a result of the late timing of initiation of N fertilization (Fig. 1d). Data from these treatments indicates that N availability can be quite tightly controlled using fertilizer injection with the drip irrigation water. After several years of study, soil residual N levels in the no N and low N treatments at the beginning of the irrigation season are down to 65 to 95 kg N ha^{-1} in the upper 90 cm of the soil.

In this second year of the study, petiole NO_3-N levels in all but the no N or low N treatments (T1, T2) remained within the University of CA recommended petiole NO_3-N levels during all growth stages. Since cotton yields were much lower in 1994 than in 1993 due to insect pressure and late planting date, it is difficult to draw a conclusion with respect to potential yield limitations due to restricted N availability in low N plots. Proper interpretation of this petiole nutrient and yield data will require analysis of soil samples to identify residual soil N that can also be available in meeting crop N requirements. Soil samples have been taken prior to and after the initial growing season, but soil total N and NO_3-N analyses for the 1994 project have not been completed at the time of this report.

All PO_4-P and K levels were consistently within the University of CA recommended petiole levels for each growth stage. The only significant interaction between petiole PO_4-P or K levels and the N treatments was for treatment T4 (high N application), which had significantly lower petiole PO_4-P and K levels than other treatments. No ready explanation was proposed for this finding.

FUTURE PLANS: Whole-plant samples were taken at four or five sample dates in each treatment, and partitioned into stem, leaves, and reproductive components, and are awaiting chemical analysis. Plant nutrient uptake and status will be compared with petiole nutrient data. This study is planned to continue for at least two years after the 1994 season.

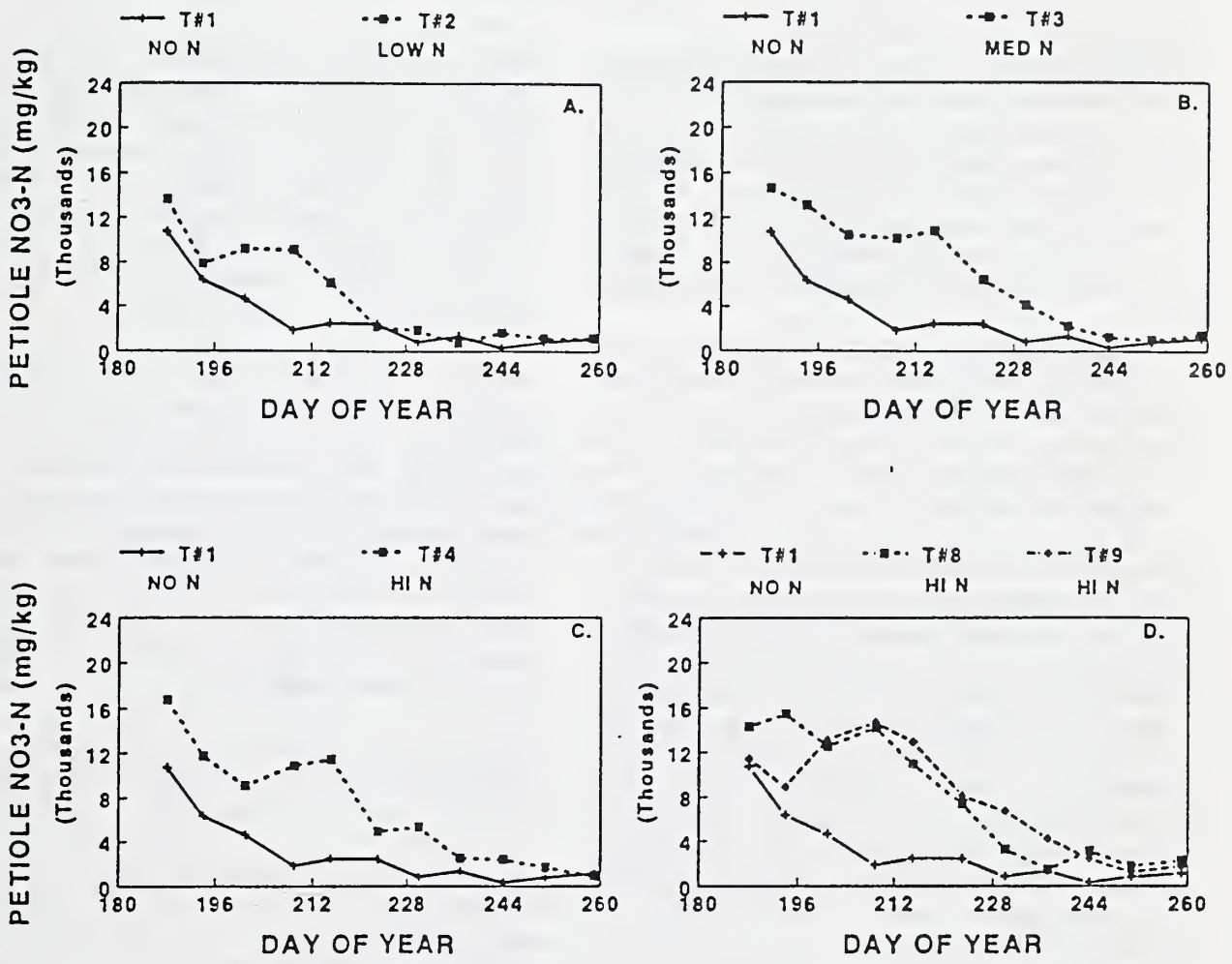


Figure 1. Cotton petiole NO_3–N means as a function of day of year and nitrogen treatment in cotton grown in a Panoche clay loam soil at the West Side Research and Extension Center near Five Points, CA in 1994. Treatments are identified in legends of Fig. 1A through 1D.

BROCCOLI RESPONSE TO SUBSURFACE DRIP LATERAL INSTALLATION DEPTH AND WATER APPLICATION AMOUNTS: I. OPERATIONAL PROCEDURES AND WATER APPLICATIONS

R.B. Hutmacher, K.R. Davis, S.S. Vail, J.E. Ayars, M.S. Peters, C. Hawk, D.A. Clark, R. Soppe, R.M. Mead, J. Liu, J. Covarrubias, A. Nevarez

OBJECTIVES: Determine the influence of subsurface drip lateral installation depth and water application amount on: (1) growth and yield of a fall/winter vegetable crop (broccoli); (2) influence on root distribution and horizontal and vertical water distribution; and (3) crop nutrient uptake and distribution in the soil profile.

PROCEDURES: The experiment was conducted in a clay loam soil (Panoche clay loam) at the West Side Research and Extension Center of the University of CA near Five Points, CA. The soil has no major obstructions to root development within the upper 2.5 m of soil. Subsurface drip laterals were installed at depths of 30, 45, and 60 cm below the surface of the beds, with uniform 1.6 m lateral spacing below the center of each 1.6 m wide bed. The field is also the site of a large (2m by 2m by 2.5 m) weighing lysimeter which can be used to determine crop evapotranspiration. The drip lateral placement in the lysimeter is 45 cm deep. All irrigation water used during the experiment came from the California Aqueduct, with an average electrical conductivity of 0.57 dS m^{-1}.

Broccoli (var. "Green Valiant") was planted on August 27, 1994. The crop was sprinkled for germination beginning September 1 (110 mm total). Each 1.6 m bed was planted with three rows 35 cm apart, and thinned to a distance of 15 cm between plants within-row. Drip lateral installation depth treatments consisted of 30, 45 and 60 cm lateral placements. Within each lateral placement treatment, there were three secondary irrigation level treatments, supplying either 70%, 100% or 130% of the estimated crop evapotranspiration (ETc). ETc was estimated using a modified crop coefficient (based on ground cover %) and grass reference ET determined from an adjacent (100 m distant) CIMIS weather station.

Total nutrient applications to the field consisted of an initial broadcast application of 20 kg N ha^{-1}, 85 kg P ha^{-1}, and 64 kg K ha^{-1}. In addition, N and P were supplied through the drip system with all drip water applications in amounts proportioned to match plant N and P uptake. Total amounts applied through the drip system were 45 kg P ha^{-1} and 189 kg N ha^{-1}.

Initial and ending soil water content (after germination sprinkling was completed and again post-harvest) was determined gravimetrically using soil samples collected to a depth of 1.35 m at 15 cm increments at locations 10, 40 and 70 cm from the drip lateral. Neutron access tubes were installed to a depth of 2.2 m and monitored using neutron attenuation tubes in plots from limited treatments/blocks to monitor potential deep percolation.

RESULTS: Water applications for germinating seed (with sprinklers) totalled 110 mm between late-August and mid-September in all irrigation treatments. Rainfall between August 1994 and harvest in January of 1995 totalled 167 mm, with 78 mm of that amount occuring in the months of August through December, and 89 mm in January prior to harvest.

Average total accumulated irrigation in the 70%, 100% and 130% ETc irrigation subtreatments was 166 mm, 198 mm and 234 mm, respectively (Table 1). Drip irrigation plus rainfall totalled 333 mm, 365 mm and 401 mm in the 70%, 100%, and 130% ETc irrigation treatments, compared with 342 mm of grass reference ETo during the period from planting through harvest. Net change in soil water content determined for the period from mid-September (after germination sprinkling) through late-January (post-harvest) averaged 7 mm, +12, and +41 mm in the 70%, 100%, and 130% ETc treatments, respectively, for average ETc estimates of

Table 1. Water balance for drip lateral depth and irrigation level sub-treatments in subsurface drip irrigated broccoli in 1994-1995 at the West Side Research and Extension Center of the University of CA.

Drip lateral installation depth (cm)	Irrigation treatment (% ETc)	Water applied - drip (mm)	Change in soil water content[z] (mm)	Estimated ETc[y] (mm)
30	70	167	-7	341
	100	198	+18	347
	130	231	+46	352
45	70	170	-12	349
	100	201	+31	337
	130	235	+34	368
60	70	160	-3	330
	100	195	-12	374
	130	236	+42	361

[z] change in soil water content between mid-September (after sprinkler irrigation) and 12 days post-harvest (late January)
[y] sum of drip irrigation applications, rain, and change in soil water content - assumes no deep percolation.

340, 353, and 360 mm. These calculated water balances assume no deep percolation. During the high rainfall in months like January, deep percolation could have occurred, but data from neutron access tubes was inconclusive for determining deep percolation.

The abnormally high rainfall totals during the winter of 1994/1995 essentially eliminated any chance of significant treatment differences in plant water status, with all treatments showing no evidence of significant water deficits at any measured time. While there were continuing problems with substantial periods of erratic readings in the weighing lysimeter, a crop coefficient was developed for fall/winter broccoli (data not shown) and can be used in future studies.

FUTURE PLANS: This experiment will continue on a rotation to include both summer and winter vegetable crops. Current plans are to use a broccoli/ cantaloupe rotation for the next two to three years and follow both plant response to drip lateral and water application amount treatments, but also follow plant nutrient uptake and soil nutrient distribution under this type of management system. Cantaloupe will be planted during April and harvested in July, while broccoli will next be planted in August of 1995.

Soil Water Monitoring: Soil matric potential was monitored in three grids of 9 heat-dissipation matric potential sensors in each lateral installation depth treatment. The grid consisted of sensors at approximate 0.3 m intervals horizontally and vertically along a plane perpendicular to emitter locations. This data was collected , along with soil gravimetric and neutron attenuation measurements of soil water content, to compare with a computer model simulation of soil water movement around subsurface drip emitters. Due to the excessive winter rain at this location during the broccoli growing season, no large fluctuations in soil matric potential were noted during the latter two-thirds of the growing season.

BROCCOLI RESPONSE TO SUBSURFACE DRIP LATERAL INSTALLATION DEPTH AND WATER APPLICATION AMOUNTS: II. GROWTH, YIELD NUTRIENT STATUS AND UPTAKE

R.B. Hutmacher, K.R. Davis, S.S. Vail, J.E. Ayars, M.S. Peters, C. Hawk, D.A. Clark, R. Soppe, R.M. Mead, J. Liu, J. Covarrubias, A. Nevarez

OBJECTIVES: Determine the influence of subsurface drip lateral installation depth and water application amount on: (1) growth and yield of a fall/winter vegetable crop (broccoli); (2) influence on root distribution and horizontal and vertical water distribution; and (3) crop nutrient uptake and distribution in the soil profile.

PROCEDURES: The basic experiment was as described in "Broccoli Response to Subsurface Drip Lateral Installation Depth and Water Application Amounts: "Operational Procedures" elsewhere in this volume.

Uppermost fully-expanded, fully-illuminated leaves were sampled for mid-rib and leaf blade nutrient status four times during the growing season, with NO3-N, total N, P, and K determined on all samples. In addition, end-of-season plant samples were collected, partitioned into broccoli heads, upper 50% leaves, lower 50% leaves, stem, and upper root and analyzed for N, P and K content.

The harvest consisted of two harvests, 6 days apart, on January 13 and January 19, 1995. Each harvest area was separated into a north, south and central row and harvested and weighted individually. The heads were cut to a uniform stem base-to-floret-tip length of 20 cm, sorted by head diameter (<3", 3"-5", and >5") and fresh weights determined on each size category.

RESULTS/DISCUSSION: There were no significant differences in yield of marketable broccoli among the lateral installation depth treatments, with averages across all irrigation amounts of 17.4 Mg ha^{-1}, 16.8 Mg ha^{-1} and 17.3 Mg ha^{-1} in the 30 cm, 45 cm and 60 cm installation depth treatments, respectively (Fig. 1). Average marketable yields across all lateral depths for each of the irrigation amounts were also not significantly different, averaging 17.2 Mg ha^{-1}, 17.0 Mg ha^{-1} and 17.3 Mg ha^{-1} in the 70% ETc, 100% ETc and 130% ETc water application treatments, respectively. The lack of yield and growth differences across treatments is certainly related to the high winter rainfall during the November through January period, which reduced total irrigation requirements and

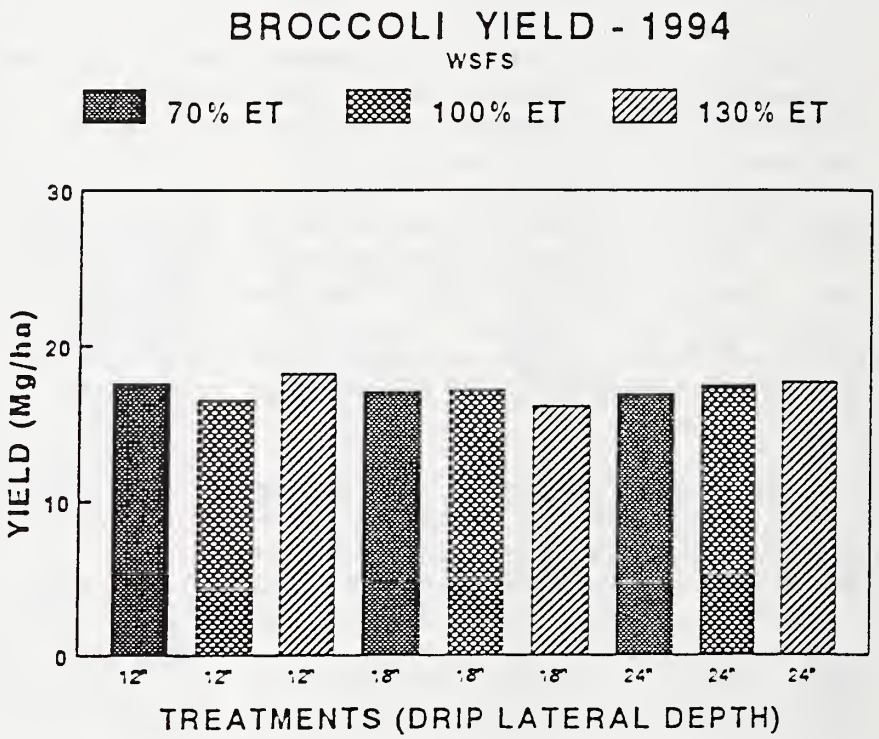


Fig. 1. Total marketable broccoli yield from two harvest dates in January 1995 at the West Side Research and Extension Center of the University of CA as a function of drip lateral installation depth treatments (12", 18", 24") and irrigation application treatments (70% ETc, 100% ETc and 130% ETc).

prevented soil water deficits even in the low irrigation treatments.

Broccoli heads were significantly larger in the southernmost of the three rows per east-west bed, with an average of 45% of the yield (expressed as fresh weight of marketable heads) coming from the south row of each bed and the remainder split evenly between center and north rows (data not shown). This was related mostly to better sun exposure and more robust plants in the southern row (an average of 22% larger leaf area and 16% higher total dry matter than in plants from center or north rows, even at 67 days after planting). Average final plant populations were not significantly different across treatments (all-treatment average of 88,000 plants ha^{-1}). Peak leaf area indices (measured 12 days prior to the final harvest) were not significantly different across any treatments and averaged in excess of 3.9 in all treatments (overall average of 4.6 m^2 m^{-2}). In mid-December, soil/root samples collected in the center of the bed, under the outer plant row and edge of bed indicated significant root densities (>0.3 cm g^{-1} soil dry wt.) extending only to depths of 0.9 m, 0.8 m and 0.65 m, respectively.

During mid-vegetative growth (late October / early November, prior to bud development), NO_3-N levels in midribs of recently mature leaves were significantly lower in treatments with deep drip lateral placement (Table 1). Data discussed here represent samples consisting of equal numbers of mid-ribs from center, south and north rows of each sampled bed. Similar trends were observed during floret expansion, although differences were generally not as large. During the vegetative period, mid-rib NO_3-N, PO_4-P, and K concentrations were non-limiting in the 30 and 45 cm lateral depth treatments according to University of CA guidelines, and mid-rib levels in 60 cm lateral depth treatments were borderline deficient. During floret development, mid-rib PO_4-P and K levels were below University of CA guidelines for "sufficient" but were above "deficient" levels. Although some roots were evident at greater than 60 cm depth even in late October, higher root densities prevailed in the upper 45 cm, perhaps limiting availability of applied nitrogen in the 60 cm lateral depth treatments. There was no general interaction between irrigation treatment and lateral placement that influenced mid-rib NO_3-N, PO_4-P or K concentrations.

The lower early-season and mid-season mid-rib NO_3-N concentrations may be due in part to the small amount of pre-plant or sidedress N applied compared to typical commercial practices under furrow irrigation. Since yields were high compared to other Fresno County broccoli farms, the differences in mid-rib NO_3-N, PO_4-P, and K concentrations found in this study may indicate a more typical response when little pre-plant fertilizer is applied and most fertilizer is applied with the drip system during the growing season.

FUTURE PLANS: This experiment will continue on a rotation to include both summer and winter vegetable crops. Current plans are to use a broccoli/ cantaloupe rotation for the next two to three years and follow both plant response to drip lateral and water application amount treatments, but also follow plant nutrient uptake and soil nutrient distribution under this type of management system. Cantaloupe will be planted during April and harvested in July, while broccoli will next be planted in August of 1995.

Table 1. Concentrations of NO3-N, PO4-P, and K in mid-ribs of recently-mature leaves of broccoli as a function of irrigation treatment and drip lateral placement at two growth stages (1) vegetative: October 20; and (2) beginning of floret expansion (December 6). Project was at the West Side Research and Extension Center of the University of CA near Five Points, CA.

Drip lateral placement (cm depth)	Irrigation treatment (% ETc)	Vegetative Stage Mid-rib concentration ($mg\ kg^{-1}$) NO3-N	PO4-P	K	Floret Expansion Mid-rib concentration ($mg\ kg^{-1}$) NO3-N	PO4-P	K
30	70	9570a[z]	4640a	50270a	7340a	2940a	35000a
	130	9060a	4630a	47200a	7120a	3270a	35900a
45	70	9130a	4440a	53600a	6750b	3300a	33200a
	130	9400a	4700a	50600a	7080ab	3330a	33800a
60	70	7460b	3920a	49800a	6720b	3820a	30400a
	130	7400b	4290a	49490a	7760a	3520a	31000a

[z]means within a column followed by different letters are significantly different at the 5% level.

NITROGEN UPTAKE OF ACALA AND PIMA COTTON UNDER HIGH-YIELD, DRIP IRRIGATION CONDITIONS: I. OPERATIONAL PROCEDURES

R.B. Hutmacher, C.J. Phene, K.R. Davis, S.S. Vail,
T. Pflaum, M.S. Peters, C.A. Hawk, and D.A. Clark

OBJECTIVES: This project was initiated to: (1) determine growth and yield responses of specific Acala and Pima cotton varieties to high frequency subsurface drip irrigation in quantities ranging from moderate to mild water deficits, and (2) uptake responses to a range of amounts and timing of water applications. The primary field experiment was concluded in 1993, however, the nutrient analyses on soil and plant tissue samples continued during 1994.

PROCEDURES: *Site Conditions / Drip Systems / Basic Measurements.* Cotton was grown in a Panoche Clay loam soil at the University of California West Side Research and Extension Center near Five Points, CA. The field was prepared in 76 cm beds and drip irrigation laterals were shanked in 45 cm deep and 152 cm apart in alternate furrows. The drip line installed was 16 mm-diameter tubing with in-line, turbulent-flow emitters with a nominal flow of 4 L h^{-1} and a spacing of 0.91 m. Sand media and 200-mesh screen filters were used for water filtration. Grass reference evapotranspiration (ET_o) was determined using a large weighing lysimeter planted with a cool-season blend of grasses. Estimated ET_c was calculated by multiplying ET_o by a locally-derived crop coefficient. Irrigation frequency in all treatments was multiple times per day at a rate of 1 mm applied water following each mm of estimated ET_c. During the 1991, 1992 and 1993 seasons, average irrigation water salinity (EC_w) ranged from 0.84 to 1.35 dS m^{-1}, with Boron levels of 0.6 to 1.2 mg B kg^{-1}. Water of lower salinity (0.5 to 0.6 dS m^{-1}) was used in the 1993 season. A minimum of twenty petioles were collected at 7 to 10 day intervals from each of three field replicates of each treatment for evaluation of crop NO_3-N, P and K status. Petioles were collected from the fourth or fifth most recent main stem node prior to 0930 hours PDT.

Cotton was planted on day 98 (1991), day 97 (1992), and day 109 (1993) and one 27 m row was harvested per plot on day 294 (1991), 301 (1992), and 314 (1993) using a single-row spindle picker. Sprinkler applications (both pre-plant and for germination) totalled 142 mm in 1991, 151 mm (1992), and 126 mm (1993). Cotton growth and development were monitored throughout the season using measurements of height, nodes above white flower, and during five measurement dates, complete plant growth analysis including flower and boll counts, plant component dry weight, and leaf area. Plant samples collected at these five times were dried at 50°C, bulk samples of 15 plants were composited within each treatment, run through a chipper, mixed, and representative subsamples were ground in a cyclone mill for subsequent elemental analysis. Plant mapping data was collected at intervals during the season by Dr. T.A. Kerby and staff, but will not be reported here.

Early to mid-season leaf water potentials (LWP) were determined using a Schollander-type pressure chamber. Three subsamples per field replicate were evaluated for each treatment. Fully-illuminated, recently-mature leaves from the fourth or fifth most recent main stem node were collected in mid-afternoon (1300 to 1500 hours, PDT), placed in a plastic bag, excised, and stored in humid, sealed plastic containers. Infrared thermometer and psychrometer data for determination of the crop water stress index (CWSI) were collected according to the methods of Idso (1982). Soil water content was monitored to a depth of 3.1 m by neutron attenuation throughout each season. Actual ET_c was calculated as applied water plus rainfall, plus soil water depletion, assuming negligible deep percolation. Soil samples were collected in both studies after seedling emergence and again post-harvest to a depth of 2.25 to 3 m (depending on the year) to identify changes in stored soil nutrients and salinity occurring with prevailing irrigation and nutrient management. Saturation extracts were

prepared from all samples and analyzed for EC, pH, NO_3-N, P, K and Cl. Total N will be determined on selected samples.

Six subsurface drip irrigation treatments were imposed on two Acala types (GC-510, Columnar C2), and one Pima type (Pima S6) in 1991, 1992 and 1993. The irrigation treatments (Table 1) represent combinations of different water application rates and different timing of deficit irrigation during the growing season. Each field plot was ten 0.76 m rows wide by 28 m in length. Three replicates of each treatment were arranged in a randomized complete block design. Each plot received a PIX (mepiquat chloride) application of 0.9 L PIX ha^{-1} (1991, 1992, 1994) or 1.1 L PIX ha^{-1} (1993) during early bloom. Approximately 168 mm of rain fell from December 1990 to March 1991, 195 mm from December 1991 to March 1992, and 211 mm from December 1992 through March 1993.

Table 1. Water application rates as a function of time of year in subsurface drip irrigation treatments (Experiment One) in 1991, 1992 and 1993 in cotton deficit irrigation study at the University of California West Side Research and Experiment Center near Five Points, CA.

Days of year	Water application rates during specific periods (percent of ET_c) Irrigation treatments					
	T1	T2	T3	T4	T5	T6
148 to 177	100	100	100	100	100	100
173 to 187	100	100	100	100	80	60
188 to 212	100	100	100	80	80	60
213 to 248	100	80	60	60	80	60

A flow-sensing proportioning pump was used to continuously inject liquid fertilizer into the drip system. Nitrogen was applied as calcium-ammonium nitrate during June and July, and potassium nitrate was used as the N and K source during August. These nutrient sources were used to apply a higher N-content material (calcium-ammonium nitrate) during the peak N demand period (early to mid-season) and a lower N-content material and supplemental K during the high K uptake period (mid to late-season). Phosphoric acid was injected to provide phosphorus. Total N, P and K applications were similar across the three years of the study, with 212, 83, and 111 kg ha^{-1}, respectively, in 1991, 203, 84 and 126 kg ha^{-1} in 1992, and 205, 87 and 130 kg ha^{-1}, respectively in 1993.

RESULTS: See following report in this volume.

FUTURE PLANS: The field experiment described here was terminated in 1994, and the field rotated into another cotton experiment focusing on determination of critical N requirements for growth and yield in irrigated cotton production. Chemical analyses are completed for 1991 and 1992 plant samples and will soon be completed on all samples from the 1993 experiment. When N, P, and K analyses are complete for all sampling dates, a manuscript will be prepared outlining cotton nutrient uptake under high-yield, subsurface drip irrigation conditions.

NITROGEN UPTAKE OF ACALA AND PIMA COTTON UNDER HIGH YIELD, DRIP IRRIGATION CONDITIONS: II. CROP RESPONSES

R.B. Hutmacher, C.J. Phene, K.R. Davis,
S.S. Vail, T. Pflaum, M.S. Peters, C.A. Hawk, D.A. Clark

OBJECTIVES: This project was initiated to: (1) determine growth and yield responses of specific Acala and Pima cotton varieties to high frequency subsurface drip irrigation in quantities ranging from moderate to mild water deficits, and (2) to identify specific plant growth, gas exchange and nutrient uptake responses to irrigation treatments. The primary field experiment was concluded in 1993 and reported on in part in previous annual reports, however, the nutrient analyses on soil and plant tissue samples continued during 1994.

PROCEDURES: Procedures used were detailed in previous report entitled "Nitrogen Uptake of Acala and Pima Cotton Under High Yield, Drip Irrigation Conditions: I. Operational Procedures".

RESULTS AND DISCUSSION: *Water Use and Plant Water Status.* Details of evapotranspiration and soil water depletion patterns in this study were summarized in prior years and will not be repeated in detail here. A brief discussion will be included here to identify the relative levels of water deficits produced across treatments. Calculated whole-season ET_c in 1991 ranged from a low of 538 mm in treatment T4 (Pima) to a high of 749 mm in treatment T3 (Columnar). In general, ET_c of the Pima was lower than in the Acala due to lower soil water depletion in the Pima. Extensive use of stored soil water resulted in relatively high ET_c values even in the 60% and 80% ET_c treatments. In 1992, total season ET_c ranged from 590 to 882 mm. In 1992 (between day 148 and 178), 80 to 100 mm water, in excess of ET_c, was applied to replenish soil water depleted during 1991. Extensive stored soil water use in all irrigation treatments and varieties resulted in similar ET_c values within treatments in Acala and Pima varieties in 1993 and a tighter range of estimated ET_c across varieties than in the other two years.

Water deficits were mild in the 100% ET_c (T1) treatment, with even the -1.5 MPa LWP corresponding with a CWSI value less than 0.1. In contrast, the LWP in the treatments receiving the least water (T5, T6) declined to -1.7 MPa by day 200 and to less than -2.0 MPa by day 215, with more severe late season reductions in LWP in 1992 and 1993. Within any irrigation treatment, few significant differences in mid-afternoon leaf water potential (LWP) existed between the Columnar and GC-510 varieties. Across all irrigation treatments, Pima cotton exhibited 0.1 to 0.2 MPa lower afternoon LWP than the Acala varieties in both years. Since the drip system applied water multiple times per day but in deficit amounts in most treatments, stress developed gradually and plants typically extracted a minimum of 200 mm, and in many cases, in excess of 300 mm of stored soil water to supplement applied water. LWP differences were largest during the boll-filling period, when available stored soil water had been depleted in much of the soil profile in low water treatments.

Growth Components and Lint Yield. Seed cotton and lint yields across treatments in both years were all within a relatively narrow range. Pima lint yields (1991, 1992) ranged from about 1944 to 2296 kg ha^{-1} with an average of 2098 kg ha^{-1}; GC-510 ranged from 2128 to 2674 kg ha^{-1} with an average of 2440 kg ha^{-1}, and Columnar ranged from 2193 to 2383 kg ha^{-1} with an average of 2298 kg ha^{-1}. 1993 yields across all irrigation treatments were 70-78 percent of average yields in 1991 and 1992.

This subsurface drip irrigation experiment demonstrated that the potential exists to achieve high lint cotton yields with relatively low ET_c and essentially no deep percolation. Water use efficiencies approach 3.5 kg lint/ha/mm ET_c, which is extremely high compared to most cotton

production in California's San Joaquin Valley.

Petiole Nutrient Status. Irrigation treatments did not significantly influence petiole NO_3-N in Acala or Pima varieties (Fig. 1a, 1b). Early-season petiole nitrate levels in all three varieties were generally lower than University of California recommendations for Acala varieties, while mid and late-season values were closer to recommended levels (Fig. 1). Petiole NO_3-N levels of the Pima cotton were significantly lower than in the Acala types (particularly prior to day 210), despite identical nutrient applications. Petiole PO_4-P and K levels were not significantly different across varieties (data not shown). In all treatments, PO_4-P levels were consistently lower than University of California recommendations for Acala varieties, while petiole K levels were generally close to the recommended range during the season. Soil N data collected prior to and following the 1991 season indicated that low soil N levels prevailed both before and after the crop season. This suggests little carryover of N from prior crops. Soil NO_3-N levels were generally quite low both at the beginning and end of each crop in the 3-year project, with 5-25 mg NO_3-N kg^{-1} soil in the upper 45 cm of soil and <3 mg kg^{-1} below. Soil PO_4-P values similarly were quite low, with 15-30 mg PO_4-P kg^{-1} soil in the upper 20 cm and <8 mg kg^{-1} below. Since lint yields were high in all plots despite what could be regarded as low residual soil N and barely sufficient petiole nutrient levels during some growth stages, this data may indicate a need to reevaluate guidelines for petiole nutrient levels for high-yielding, drip-irrigated cotton.

Above-Ground Plant Tissue N Content. Accumulation of total N in above-ground tissues was high and quite consistent across varieties (Fig. 2). Lower accumulations in more severe water deficit treatments (T6) were associated mostly with reductions in leaf and stem dry weights, not with reductions in N concentrations in leaf, stem or reproductive tissue (leaf data only shown in Fig. 3). Averaged across Acala and Pima types, above-ground plant N accumulations expressed per unit lint yield averaged 10.9 kg N per 100 kg lint.

FUTURE PLANS: This field experiment was terminated in 1993 and a new project was initiated with specific emphasis on nitrogen management of cotton under drip irrigation. This data will be used in conjunction with plant dry matter and growth data in evaluations with the CALGOS cotton model and will be included in manuscripts to be prepared during 1995.

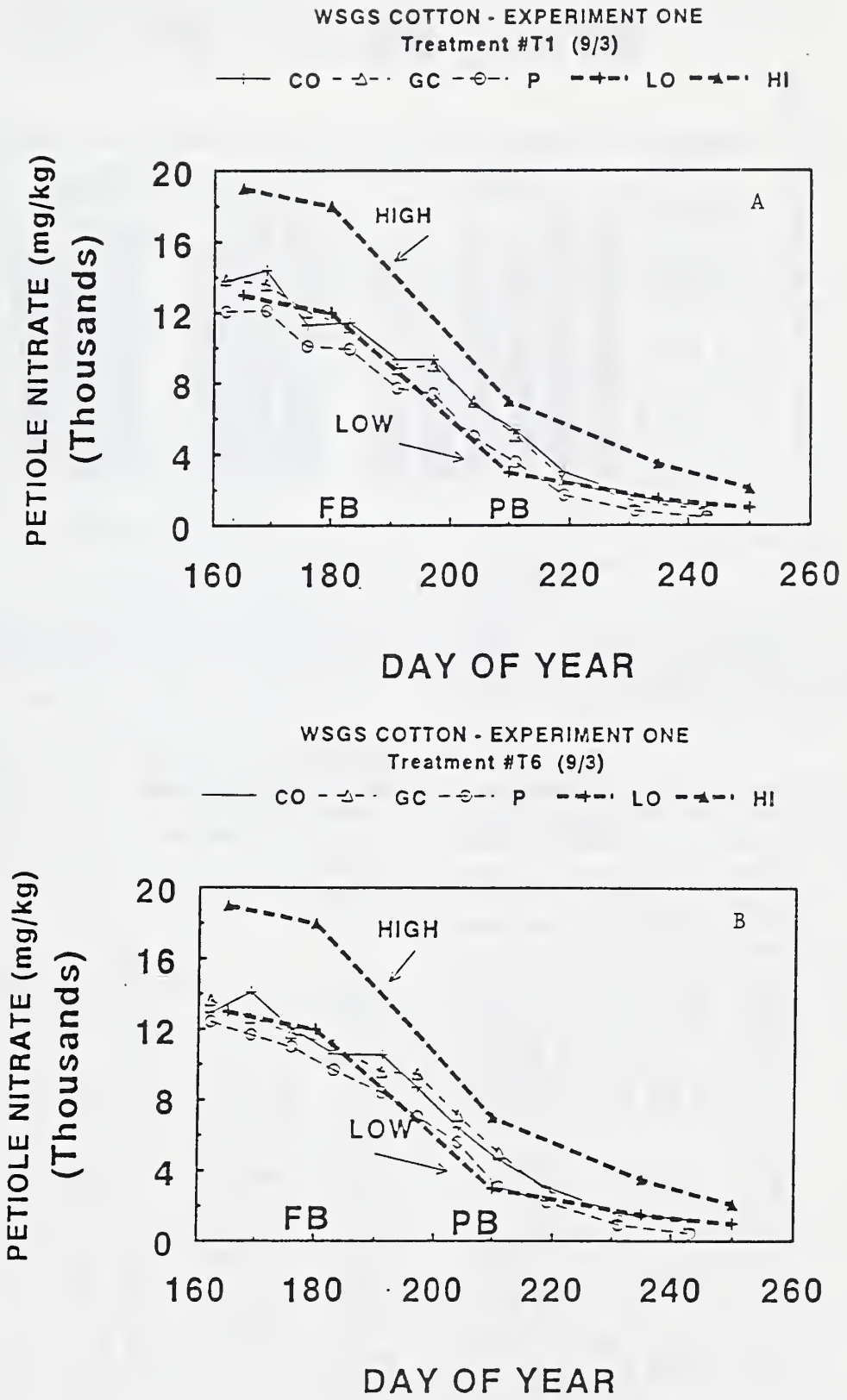


Figure 1. Nitrate-N content of cotton petioles from the most recent fully-expanded leaf (fifth node from the top of main stem) as a function of day of year and cotton type for (A) irrigation treatment T1, and (B) irrigation-treatment T6 in 1993. Upper and lower dashed lines marked "HIGH" and "LOW" represent upper and lower limits for University of CA guidelines for recommended petiole nitrate-N during the season. Average dates for first bloom ("FB") and peak bloom ("PB") are indicated on the y-axis.

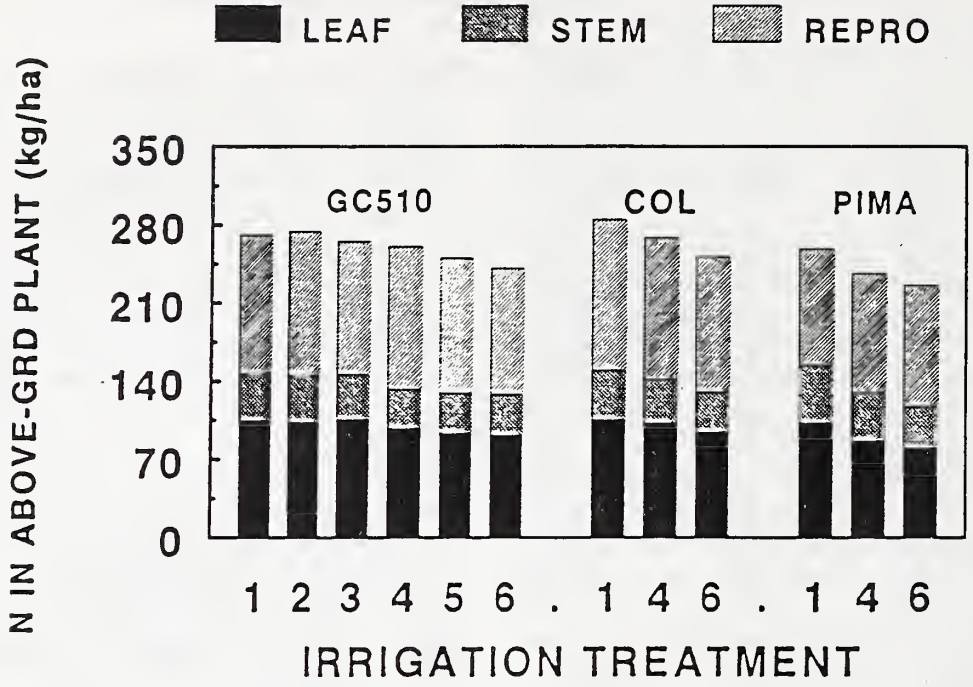


Figure 2. Average amount of nitrogen (N) contained in above-ground leaf, stem and reproductive tissue in late-August of 1992 as a function of irrigation treatment and cotton type. Cotton was grown under drip irrigation at the West Side Research and Extension Center near Five Points, CA.

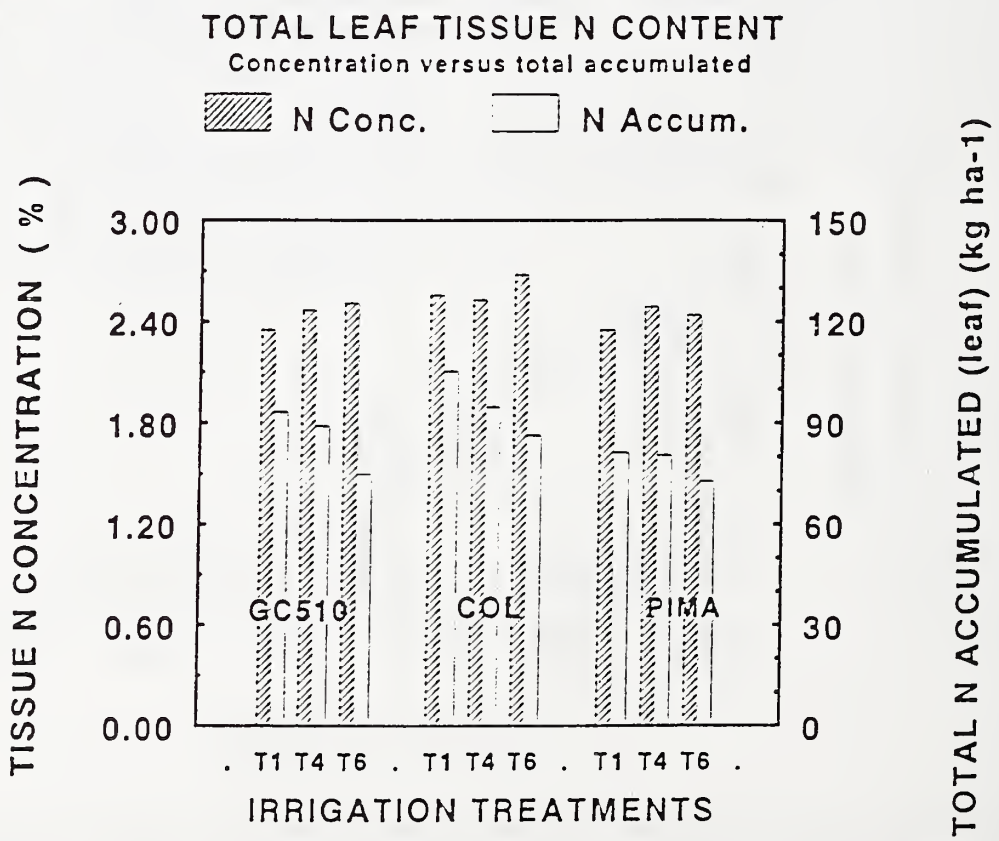


Figure 3. Average nitrogen (N) concentration in leaf tissue and N accumulated in all leaf tissue in late-August, 1992 as a function of irrigation treatment and cotton type. Cotton was grown under subsurface drip irrigation at the West Side Research and Extension Center near Five Points, CA.

FOLIAR METHANOL APPLICATIONS: EFFECTS ON COTTON GAS EXCHANGE, GROWTH, YIELD IN CONTAINER-GROWN PLANTS

R.B. Hutmacher

OBJECTIVE: During the past two years, information from an Arizona farmer and a California researcher implicated foliar methanol applications in improvements in cotton and vegetable crop yields under desert conditions. These findings received a great deal of attention at industry meetings and the popular press. In response to a nationwide effort initiated by Dr. John Radin of the USDA-ARS National Program Staff to involve cotton researchers in investigating the potential influence of methanol on crop water use and yield, we participated in an investigation of the influence of a range of concentrations of methanol applied at specific growth stages on cotton leaf conductance, photosynthetic rates, overall plant growth and boll production. Preliminary findings from 1993 were that methanol was generally ineffective in producing consistent yield responses, particularly under field conditions, but some measurements on container-grown plants suggested favorable gas exchange responses at the single leaf level. Additional measurements were made during 1994 to further test these suggested responses.

PROCEDURES: All container-grown plant studies were in 7 liter containers with 6 replications per treatment. Two container studies also conducted in 1993 were repeated and expanded during 1994; (*EXPERIMENT 1*) effects of timing of application (2 sprays at 24% methanol/week for a three week or a six week period beginning at weekly intervals starting at the third true leaf stage (May 9) and continuing though first flower (late June) - in addition, treatments of late-season applications (twice per week for three weeks) starting on July 22 and August 4 were made on previously un-treated plants; (*EXPERIMENT 2*) effects of number of spray methanol applications (combination of 1 or 2 applications of 24% methanol solution per week for duration of 1, 2, or 4 weeks). All plants received water from one drip emitter per container and received liquid fertilizer applied with the water.

RESULTS AND DISCUSSION: Summarized as follows for individual experiments:
EXPERIMENT 1: (spray timing effects) Plants sprayed twice per week with the 24% methanol solution beginning at the third leaf stage (5/09) or beginning at weekly intervals through pinhead square (about 6/01) averaged 7% larger total dry matter (measured at peak bloom), and 6% larger total dry matter (measured at first open boll) than the average total dry matter for other treatments (Table 1). As in 1993, plants in which spray treatments began earlier tended to be taller than in those spray treatments initiated later in the season. Variability across replications meant that some of these apparent differences were not significant.

The duration of the treatments did not significantly influence observed results, although in some treatments there was a trend (not significant) toward reduced dry matter and height responses with short duration (3 week) treatments. Late-season applications in July and August had no effect on dry matter or height. No visual symptoms of phytotoxicity from methanol applications were observed in any treatments with the exception of plants initially treated on 5/16. No explanation for this effect was apparent.

EXPERIMENT 2: (number of spray applications): Final plant total dry matter and plant height did not respond consistently to the number of spray applications, although some tendency existed for larger plants (about 3 to 7% larger) in treatments receiving methanol applications twice per week for a 2 or 4 week period). Unlike results from 1993, growth responses were only observed with two applications per week). Responses were variable and often not significantly different across treatments. In general, data from 1994 container studies indicated that effects of

Table 1. Methanol spray timing effects on dry matter and plant height in container-grown cotton, 1994, as a function of starting date for three week or six week applications of 24% methanol solution applied to entire plants.

Date of initiation of 24% methanol treatment	Duration of spray treatment (weeks)	Total dry matter (expressed as % of 0% methanol control trt.)		Plant height (expressed as % of 0% methanol control trt.)	
		At peak bloom	At 1st open boll	At peak bloom	At 1st open boll
5/09	3	109	105	102	104
	6	106	108	96	98
5/16	3	95	98	98	101
	6	104	105	102	99
5/23	3	106	104	107	106
	6	108	111	103	107
5/30	3	105	102	104	106
	6	109	110	108	104
6/06	3	102	97	95	98
	6	99	103	97	95
6/11	3	96	102	101	106
	6	102	99	96	100
6/16	3	95	100	102	96
	6	98	96	94	97

any methanol applications are relatively small, if any, and the greatest apparent influence is with early, frequent applications.

FUTURE PLANS: Our findings were reported in cooperation with researchers from the Texas Agricultural Experiment Station at the Agronomy meetings in 1993 and Cotton Production Conference in 1994, and a joint paper is being considered with Mr. K. Faver and Dr. T. Gerik of Texas A&M University.

FOLIAR METHANOL APPLICATIONS: EFFECTS ON TOTAL DRY MATTER PRODUCTION AND SEED COTTON YIELD IN FIELD-GROWN COTTON

R.B. Hutmacher

OBJECTIVE: During the past two years, information from an Arizona farmer and a California researcher implicated foliar methanol applications in improvements in cotton and vegetable crop yields under desert conditions. These findings received a great deal of attention at industry meetings and the popular press. In response to a nationwide effort initiated by Dr. John Radin of the USDA-ARS National Program Staff to involve cotton researchers in investigating the potential influence of methanol on crop water use and yield, we participated in an investigation of the influence of a range of concentrations of methanol applied at specific growth stages on cotton leaf conductance, photosynthetic rates, overall plant growth and boll production. Preliminary findings from 1993 were that methanol was generally ineffective in producing consistent yield responses, particularly under field conditions, but some measurements on container-grown plants suggested favorable gas exchange responses at the single leaf level. Results from a 1993 field study did not indicate significant yield or total dry matter responses to methanol applications. Additional measurements were made during 1994 to further test these suggested responses.

PROCEDURES: The field test was conducted in 1993 in small subplots of a larger experiment on subsurface drip irrigated, narrow-row (0.76 m spacing) cotton (Gossypium hirsutum var. "Maxxa") grown at the University of California West Side Research and Extension Center near Five Points, CA. The field was originally intended for a cotton nitrogen study but that project was terminated due to variable plant populations. The cotton received about 410 mm of irrigation during the growing season and used an average of over 200 mm of stored soil water in the upper 2 m of the soil profile. A late-season problem with the pump resulted in an additional 135 mm of water applied during late August, but the plants had already undergone vegetative cutout at that time and the late-season water did not markedly influence growth and yields (few late-season flowers and bolls produced).

The crop was subject to few significant water deficits prior to late-June, with leaf water potentials (LWP) generally greater than -1.6 MPa. After mid-flowering (mid-July), water stress developed in all plots with crop water stress index (CWSI) values varying between 0.15 and 0.3 and LWP values less than -1.7 to -2.0 MPa.

Only phosphoric acid was applied as a P fertilizer through the drip system (59 kg P/ha).

Two field experiments were evaluated in 1994: Plot areas used in the foliar methanol applications were four rows wide (4 beds) by 12 m in length. No irrigation or fertilizer variables were tested, only different rates and timing of methanol applications. In both experiments, the only measurements made were of total plant dry matter on 3 m row sections (two beds per plot), plant height, and boll weight on plants harvested for dry matter evaluations. Seed cotton yields were estimated from boll dry weights using dry matter fraction data determined in other studies on the same variety at this site.

Experiment One. The hypothesis tested was whether a minimum number of foliar methanol applications could influence total plant growth and cotton yield. Four methanol treatments (0%, 24%, and 30% methanol, and no spray) were applied on 3 field replicates, with four separate spray date subtreatments (application of all three different rates on 6/16, 7/06, 7/23, or all three dates). Spray volume applied per treatment date was at a rate of 200 L/ha, or approximately 1.2 L per plot.

Experiment Two. Methanol (24% versus 0% control spray) was applied to field-grown

plants (twice per week for three weeks) beginning at times corresponding with expansion of the leaves at nodes 4 (treatment D1), 7 (treatment D2), and 10 (treatment D3) to evaluate potential responses during vegetative growth stages.

RESULTS AND DISCUSSION:

Experiment One. Yields were generally moderate in all plots, with estimated seed cotton yields ranging from a low of 3240 kg ha^{-1} to a high of 3580 kg ha^{-1} (data not shown). In experiment one, seed cotton yields were not significantly affected by any methanol treatment, while total dry matter production showed an apparent increase (not significant) of 6% only with the treatment sprayed with 24% methanol on all three dates. These findings were in basic agreement with results from field experiments under milder water deficit conditions in 1993. Unlike results from 1993, no phytotoxic effects were observed in any spray treatments.

Experiment Two. Estimated seed cotton yields ranged from 3460 kg ha^{-1} to 3710 kg ha^{-1} in treatments from this study, with significantly higher late-August total above-ground dry matter (6% in treatment D1, 9% in D2) and higher seed cotton yields (3% in treatment D1, 7% in D2); not significant) in the treatments with methanol sprays initiated at the 4th node and 7th node stage when compared with the 10th node spray treatment or 0% methanol control spray. Seed cotton yield estimates were variable across replications, with no clear indications of significant treatment effects on yield. Plant water status (CWSI, leaf water potential) was unaffected by methanol treatments on late-June, mid-July, and early-August measurement dates.

FUTURE PLANS: Our findings were reported in cooperation with researchers from the Texas Agricultural Experiment Station at the Agronomy meetings in 1993 and Cotton Production Conference in 1994, and a joint paper is being considered. No further field experiments are planned for the 1995 growing season.

POTASSIUM FERTILIZATION OF FRESH-MARKET TOMATOES UNDER SUBSURFACE DRIP IRRIGATION: OPERATIONAL PROCEDURES

R.B. Hutmacher, J. Liu, M. Zick, M.S. Peters
C.A. Hawk, D.A. Clark, and S.S. Vail

OBJECTIVES: Potassium fertilization is not often recommended for many agronomic and horticultural crops in the central San Joaquin Valley due to what is perceived as adequate soil potassium levels to meet plant needs. In recent years, however, crops such as cotton and some vegetable crops have responded favorably to potassium applications in San Joaquin Valley soils which usually test low to moderate in soil K. In previous studies we determined that processing tomatoes accumulate large quantities (in excess of 500 kg K ha^{-1}) under high yield conditions, and the majority of this amount is removed from the field in fruit at harvest. A field project was initiated to determine potential fresh-market tomato growth and yield responses to a range of potassium applications when applied continuously with the irrigation water under subsurface drip.

PROCEDURES: Fresh-market tomatoes (var. "Ace") were grown in a Hanford sandy loam soil in southeast Fresno on 1.52 m beds, with two planted rows, 0.3 m apart. The drip system consisted of a single drip lateral centered 45 cm below the average soil surface in each bed, with 5 beds per plot, each 13.5 m in length. The drip emitters have a nominal flow of 2 L h^{-1} at a working pressure of 124 to 138 kPa, and are 45 cm apart along each lateral.

Five fertilizer treatments were imposed as follows: (1) untreated control no potassium; (2) 137 kg K ha^{-1} applied as KNO_3; (3) 274 kg K ha^{-1} applied as KNO_3; (4) 411 kg K ha^{-1} applied as KNO_3; and (5) 411 kg K ha^{-1} applied as KCl. Each fertilizer treatment also received nitrogen and phosphorus fertilizer. Phosphoric acid was used to supply about 75 kg P ha^{-1} uniformly to all treatments as a continuous injection at a concentration of about 15 mg L^{-1}. Calcium ammonium nitrate was used to supply all N fertilizer to potassium treatments #1 and #5, while it was applied to supplement N supplied by KNO_3 in the other treatments. Total N applications for each week and for the whole season were equal across all K treatments, about 265 g N ha^{-1} in all treatments. All treatments were begun 28 days after seedling emergence. A combination of venturi-type and proportional flow injectors were used to inject fertilizer solutions. Water applications were identical across treatments, were measured using water meters, and were keyed to meet local CIMIS weather station reference evapotranspiration multiplied by a tomato crop coefficient developed at the USDA-ARS-WMRL.

The tomato seed was planted in March, thinned to 10-15 cm spacing and harvested in July and August, with three harvests at about 10 day intervals. Fruit was classified according to size and quality characteristics, with fruit average size in each class and total fruit number recorded. Fruit were characterized based on color and size and classified as marketable or unmarketable (sunscald, rotten, broken skin). Petioles of upper canopy fully-illuminated and expanded leaves were collected at 7 day intervals and NO_3-N, PO_4-P and K levels were determined. Leaf blades from the same locations as petiole samples were collected to evaluate plant storage of nutrients. Plant water status was monitored using crop water stress index (CWSI) and leaf water potential (LWP) methods. Plant above-ground dry matter samples were collected four times during the growing season to determine growth responses to K treatments and to provide dry matter weights and samples for determining nutrient uptake as a function of growth stage.

RESULTS AND DISCUSSION: See accompanying report for details of yield, growth, and petiole nutrient status. This project will serve as a Master of Science Thesis project for a student at California State University, Fresno.

Growth measurements were expressed as total fruit fresh weight, average fruit size and number per unit ground area, total plant dry matter and leaf area index. Additional subsamples of component plant parts (stem, leaf, fruit) will be analyzed to determine nutrient (N, P, K, Ca, Mg, Cl) concentrations as a function of growth stage and to calculate nutrient uptake amounts.

Soil samples were taken prior to beginning nutrient applications and post-harvest to determine initial soil nutrient status and depletion/accumulation of nutrients. Soil sampling sites were 15, 30 and 45 cm laterally from the emitter locations, at 22.5 cm depth intervals between the surface and 90 cm and 30 cm intervals from 90 to 150 cm. Soil water status was monitored using gravimetric soil sampling at the beginning and end of the growing season in all treatments, and using periodic readings of 10 neutron access tubes in treatments #1 and #4.

FUTURE PLANS: Summary reports will be prepared and submitted to Vicksburg Chemical Co., a cooperator in this study.

POTASSIUM FERTILIZATION OF FRESH-MARKET TOMATOES UNDER SUBSURFACE DRIP IRRIGATION: II. GROWTH, YIELD, PETIOLE NUTRIENT STATUS

R.B. Hutmacher, C.J. Phene, J. Liu, M. Zick,
M.S. Peters, C.A. Hawk, D.A. Clark

OBJECTIVES: It has been determined in previous studies that processing tomatoes accumulate large quantites of Potassium (in excess of 500 g K ha^{-1}) under high yield conditions, and the majority of this is removed from the field in fruit at harvest. This project was initiated to determine potential fresh market tomato growth and yield responses to a range of potassium applications when applied continuously with the irrigaton water under subsurface drip. For further information see "Potassium Fertilization of Fresh-Market Tomatoes under Subsurface Drip Irrigation: Operational Procedures" in this volume.

RESULTS/DISCUSSION: *Petiole Nutrient Status.* Petiole PO_4-P (data not shown) and NO_3-N (Figure 1) levels were similar across all treatments, and the levels were within or in excess of University of California Cooperative Extension Criteria.

Petiole K levels were quite similar across treatments in the early part of the growing season (within 40 days after emergence), but did show some separation between treatments in the mid- and late-season periods (Figure 2). Petiole K levels were consistently lowest in the no K treatment (T1), but on some dates were not significantly lower than other K treatments. Data were quite variable in relative ranking across the supplemental K treatments (T2 through T5), and no consistent relative ranking or significant differences were observed other than those with the T1 (no K) treatment. These observed levels of K tended to be well-above deficient levels during most of the season, even in the T1 treatment, suggesting that available soil-K is sufficient at this site to prevent growth and yield limitations due to K.

Only a small number of plant samples for total nutient uptake have been anlyzed at the time of this report. Of those few completed at the time just prior to final harvest, total plant N uptake in above-ground tissue averages 225 kg N ha^{-1}, with over 115 kg N ha^{-1} contained in the fruit (data not shown). Total K uptake in above-ground tissue at final harvest ranges from 375 to 540 kg K ha^{-1}, with as much as 320 kg K ha^{-1} removed in the fruit.

Plant Growth and Yield Responses. Plant leaf area development in late July ranged from 6.8 m^2 m^{-2} in treatment T1 to 7.2 m^2 m^{-2} in T2 and T5, with no significant differences in plant leaf area or height noted (Table 1). Total above-ground plant dry matter (an indicator of total growth response) did show significant increases with supplemental K (Table 1).

Table 1. Mean leaf area index and total above-ground plant dry matter in late-July, 1994 as a function of K fertilizer treatment in fresh-market tomatoes grown at the USDA-ARS station in Fresno, CA. Treatment designations are as identified in text.

K fertility treatment number	Leaf area index (m^2 m^{-2})	Total above-ground plant dry matter (Mg ha^{-1})
T1	6.8 a*	12.6 b
T2	7.2 a	13.1 ab
T3	6.9 a	13.7 ab
T4	7.1 a	14.1 a
T5	7.2 a	14.5 a

*Means followed by different letters are significantly different at the 5% level.

Three hand harvests of red and breaker fruit were conducted (7/11/94, 7/21/94, and 8/01/94). In addition, green fruit were harvested at the 8/01/94 date.

On the first harvest date, higher marketable red fruit harvests were obtained in all treatments receiving supplemental K (T2 through T5) when compared with the no K treatment (T1) (Figure 3). Second harvest yields were significantly higher in T3 and T5

treatments than in no K and low K (T1 and T2) treatments (Figure 4). Third harvest yields were more variable but did show significantly higher yields in T2 and T4 than in the no K (T1) treatment (Figure 5). Total fruit yields (Table 2) (all three harvests) in the no K (T1) treatment were significantly lower than in T2, T4 and T5, but were not significantly different than in T3.

FUTURE PLANS: Despite the fact that petiole K levels across K fertilizer treatments did not indicate major differences or deficiencies until late in the season, a trend was observed toward modest increases in fruit yield and plant growth with supplemental K at this site. Soil analyses of K levels from the 1994 study, when completed, will be used to evaluate the degree to which tomato responses to supplemental K are likely. A Master of Science Thesis will be prepared using this data.

Table 2. Total marketable and unmarketable (rotten, sunscald, broken skin) for all three harvests, green fruit remaining after the third harvest, and total fruit for all three harvests as a function of K fertilizer treatment in fresh-market tomato study at the USDA-ARS in Fresno, CA, in 1994. K fertilizer treatments were as follows: (T1) untreated control receiving no potassium fertilization; (T2) 137 kg K ha^{-1} applied as KNO_3; (T3) 274 kg K ha^{-1} applied as KNO_3; and (T4) 411 kg K ha^{-1} applied as KNO_3; and (T5) 411 kg K ha^{-1} applied as KCl.

K fertility treatment number	Total marketable red fruit – combined 3 harvests (Mg/ha)	Total unmarket-able fruit – combined 3 harvests (Mg/ha)	Green fruit – third harvest (Mg/ha)	Total fruit harvest – red at 3 harvests plus green	
				(Mg/ha)	(tons/ac)
T1	59.6	3.2	22.0	84.7	37.8 b*
T2	71.7	1.6	29.1	101.9	45.4 a
T3	66.7	2.9	27.3	96.9	43.2 ab
T4	73.2	4.1	27.5	104.8	46.7 a
T5	79.3	2.0	28.1	109.4	48.8 a

*Means followed by different letters are significantly different at the 5% level.

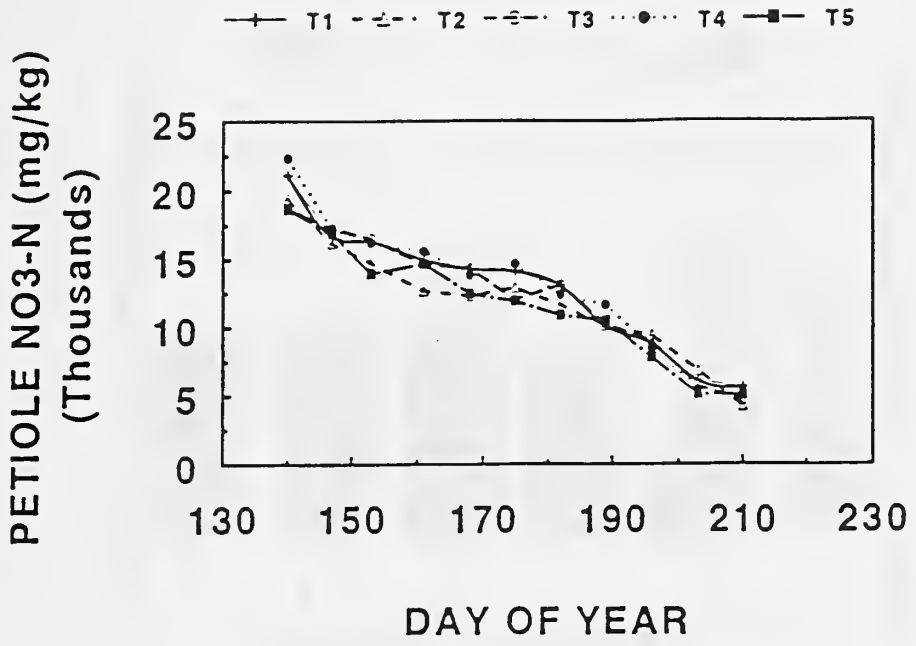


Figure 1. Petiole NO_3–N levels of uppermost fully–expanded leaves (4th or 5th most recent leaf on a main stem) as a function of day of year and K fertilizer treatment in fresh–market tomatoes grown at the USDA–ARS station in Fresno, CA in 1994. Treatments are as defined in text: (T1) untreated control receiving no potassium fertilization; (T2) 137 kg K ha^{-1} applied as KNO_3; (T3) 274 kg K ha^{-1} applied as KNO_3; (T4) 411 kg K ha^{-1} applied as KNO_3; and (T5) 411 kg K ha^{-1} applied as KCl.

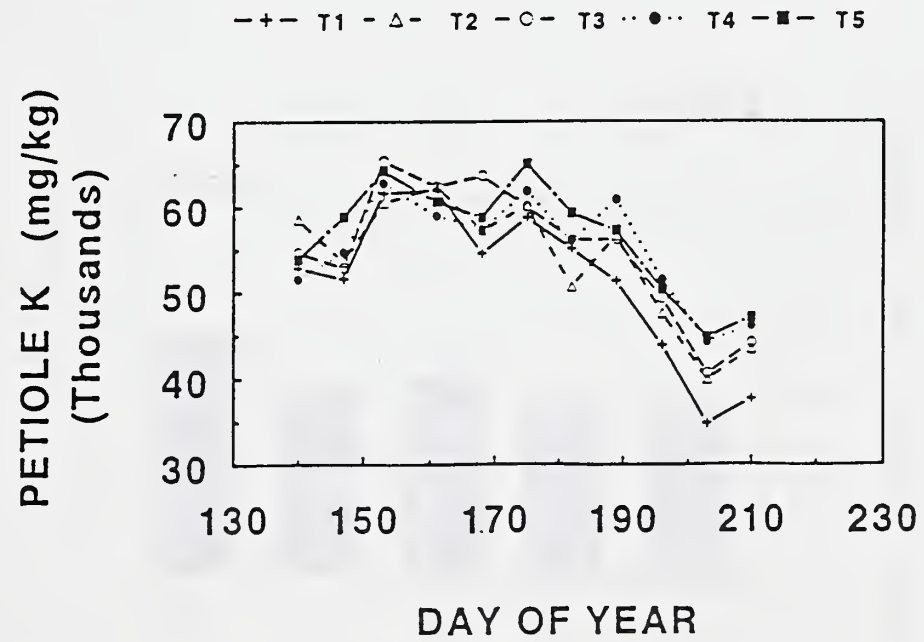


Figure 2. Petiole K levels of uppermost fully–expanded leaves (4th or 5th most recent leaf on a main stem) as a function of day of year and K fertilizer treatment in fresh–market tomatoes grown at the USDA–ARS station in Fresno, CA in 1994. Treatments are as defined in text: (T1) untreated control receiving no potassium fertilization; (T2) 137 kg K ha^{-1} applied as KNO_3; (T3) 274 kg K ha^{-1} applied as KNO_3; (T4) 411 kg K ha^{-1} applied as KNO_3; and (T5) 411 kg K ha^{-1} applied as KCl.

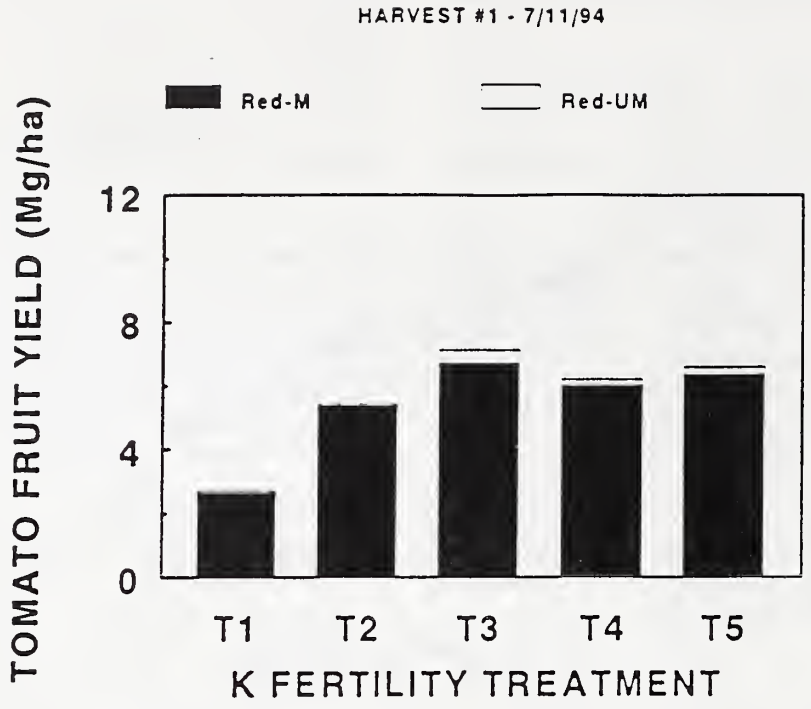


Figure 3. Yields of marketable red (M) and unmarketable red (UM) fruit at the first harvest data (July 11) as a function of K fertilizer treatment in fresh–market tomatoes in study at the USDA–ARS station in Fresno, CA in 1994.

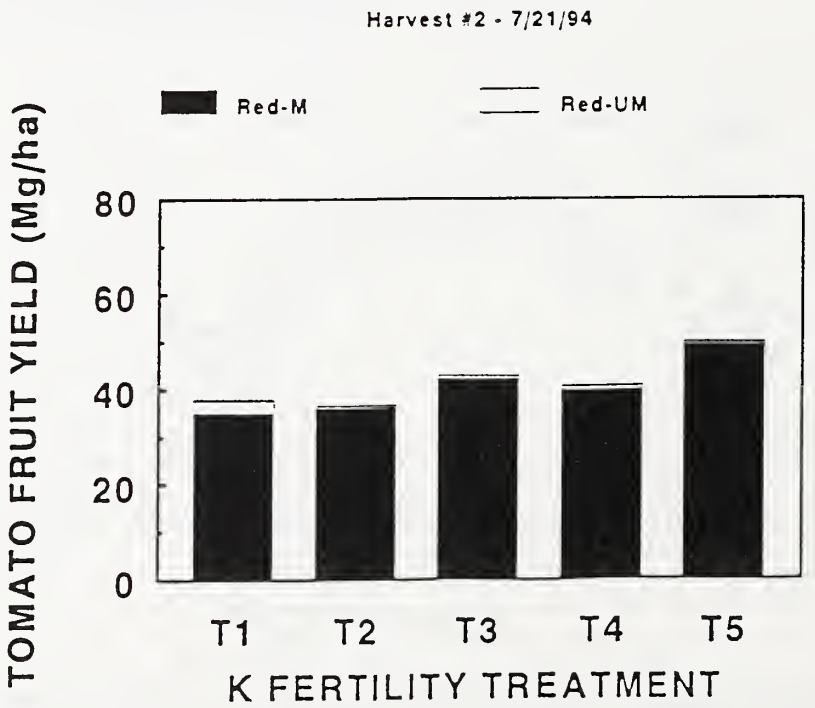


Figure 4. Yields of marketable red (M) and unmarketable red (UM) fruit at the second harvest data (July 21) as a function of K fertilizer treatment in fresh–market tomatoes in study at the USDA–ARS station in Fresno, CA in 1994.

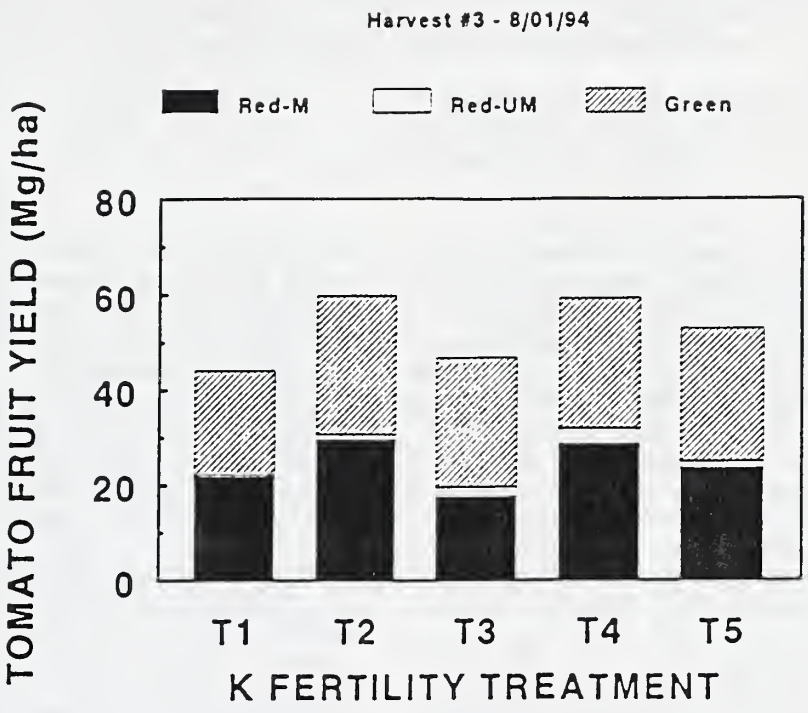


Figure 5. Yields of marketable red (M) and unmarketable red (UM) and green fruit at the third harvest data (August 1) as a function of K fertilizer treatment in fresh–market tomatoes in study at the USDA–ARS station in Fresno, CA in 1994.

MANAGEMENT OF SUBSURFACE DRIP AND FURROW IRRIGATION FOR FORAGE ALFALFA IN THE IMPERIAL VALLEY: I. OPERATIONAL PROCEDURES, WATER APPLICATIONS, EVAPOTRANSPIRATION

R.B. Hutmacher, R.M. Mead, D.A. Clark, M.S. Peters, R. Swain, P. J. Shouse, M. van Genuchten, S.S. Vail, C.A. Hawk, T Donovan, J. Jobes, J. Fargerlund, R. Kershaw, D. Currie

OBJECTIVES: The alfalfa subsurface drip/furrow irrigation experiment is a five-year long evaluation of alfalfa water requirements and the long-term influence of irrigation management on soil accumulations of salt and potentially yield-limiting specific ions. This project focuses on the comparison of crop responses, irrigation water requirements and salt accumulation as affected by subsurface drip (SDI) versus furrow irrigation. In addition, the influence of two drip tubing types and two lateral spacings (1.02 m and 2.04 m) are being evaluate.

PROCEDURES: This project was operated at the Irrigated Desert Research Station of the USDA-ARS in Brawley, CA in a Holtville silty clay soil. Alfalfa was planted on either 1.02 m (40 inch) wide beds or 2.04 m (80 inch) wide beds, depending on the irrigation treatments (described below). Seeding was in November 1993 and the seed was germinated and the crop established using 135 mm (5.4 inches) of sprinkler irrigation. The original subsurface drip system (operated from 1991 through early 1993) had a lateral installation depth of 40 to 45 cm below the bed surface, while the newer system (lateral installation depth of 63 to 70 cm) was installed in spring of 1993.

The drip laterals were placed below the center of each bed (either 1.02 m or 2.04 m in width). Two different types of drip tubing were used with each row-spacing treatment: (a) pressure-compensating in-line emitters on 20 mm tubing; and (b) turbulent-flow in-line emitters made with herbicide (trifluralin)-impregnated plastic. Both emitter types have a nominal flow of 2 L h^{-1} at 124 to 138 kPa, with 1.02 m emitter spacing. There were three field replications of each sub-treatment, with either eight 2.04 m beds or sixteen 1.02 m beds per plot. All furrow-irrigated plots were 32 beds in width, with three replications. Gated pipe was used for water delivery and typical water applications were 65 to 90 mm per irrigation, three irrigations per harvest cycle. All water applications were monitored with calibrated water meters in both furrow and drip irrigation plots. As during earlier years in this experiment, Mr. Dean Currie of Stephen Elmore Farms in Imperial, CA cooperated in helping monitor soil water and crop development to assist us in matching furrow plot irrigation scheduling with typical Imperial Valley practices on similar soils. The current lateral configuration will be evaluated at least through the 1995 calendar year.

In discussions, the original experiment will be referred to as Phase I (prior to modification of drip system) and the new system will be referred to as Phase II (after the drip system modifications - 1993 to present). The basic reason for the modifications was due to development of a few "wet" and "dry" soil surface areas (about 3% of the total bed area). "Wet" areas resulted from high emitter flows during high ET periods and flow through channels in combination with too shallow (16 inch) drip lateral placement. In addition, some malfunctioning emitters (20 to 35 in the field) with excessive flow rates contributed to the problem. The excessive flow rate problems were quite limited but were all found in the "RAM" drip tubing. The "dry" areas were extremely limited in the amount of area affected (less than 0.5% of the bed area). Evaluations indicated the causes of "dry" areas were missing emitters (20% of the "dry" problem areas) and fine silt deposition caused by filtration problems in the remaining areas. Root intrusion was not a significant cause of emitter plugging in either type of tubing.

RESULTS AND DISCUSSION: *Irrigation Scheduling, Plant Water Status and Evapotranspiration.* During Phase II, with the deeper drip tubing installation, it has not been necessary to reduce irrigations during the harvest cycle to avoid surface soil wet areas. To date (winter, 1994), the deeper lateral depth has eliminated surface "wet soil" areas and harvest equipment trafficability problems (even during high water application periods).

Water applications for all drip treatments and furrow plots were nearly identical

during 1994 (totalling 1900 mm for the year), and were 100 mm (4 inches) more than in the lysimeter-grown alfalfa (which was irrigated to replace 100 percent of ET) (Fig. 1). The extra water was applied in the late winter/spring of 1994 to build up stored soil water in the profile.

The water applications in 1994 exceed amounts applied in 1992 by more than 300 mm. The ET in 1994 exceeded that of 1992 by approximately 150 to 200 mm, partly due to higher evaporative demand during the summer months, with the difference made up by greater soil water extraction in 1992. The applied water was similar between drip and furrow irrigated treatments in 1994 for two basic reasons: (1) the lack of a cutback period in drip irrigation around harvest time resulted in higher yields, faster regrowth and therefore higher plant transpiration; and (2) the upper limit on irrigation amounts in furrow irrigated plots is restricted by soil infiltration rates.

Under conditions of minimal crop water stress in the crop lysimeter, the monthly 1994 crop ET compares closely with the monthly ET values determined in prior furrow-irrigated alfalfa lysimeter studies at the Brawley ARS site (Burl Meek, Bob LeMert, others) (Fig. 2). Lower soil evaporation under subsurface drip irrigation (SDI) explains lower monthly ET values during several summer and fall months (Fig. 3). Crop coefficients are being developed as part of this project which will relate alfalfa water use under SDI to CIMIS weather station reference ET.

Despite shallow (10 cm) shanking of each furrow following harvest, water infiltration and furrow applications typically decline significantly with each subsequent irrigation following shanking. Low infiltration rates, which occur in the second and third irrigations following harvest, continue to set the upper limit on furrow water applications. While nearly 89 to 107 mm water could be applied in the first irrigation after harvest, the second and third post-harvest irrigations would routinely accept only 61 to 79 mm. It is difficult to apply water in amounts greater than 95% of the lysimeter-measured ET_c without risking scalding injury. We have tried to counter this deficit irrigation by applying more water during the winter months, and storing it for root water uptake in high evaporative demand periods.

FUTURE PLANS: The experiment will continue through 1995, with some possibility of extension beyond that date, funds permitting. Water applications for leaching will be applied in Fall, 1995 due to salt accumulations in the surface 30 to 60 cm of soil. Annual reports will be prepared and two presentations are scheduled for ASA meetings in 1995.

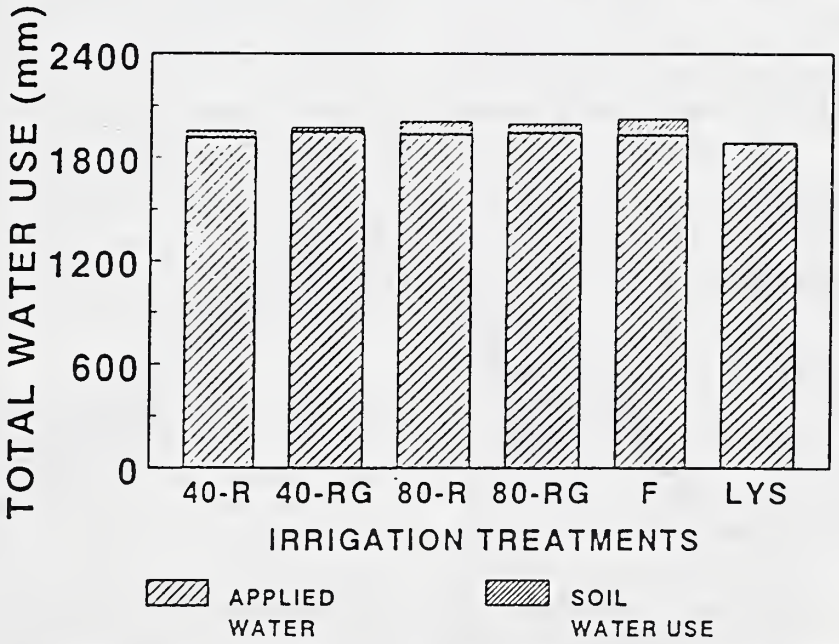


Figure 1. Full season water applications totals and soil water use in upper 2.5 m of profile in Brawley subsurface drip and furrow irrigation experiment from all sources (drip, sprinklers, furrow) in 1994 as a function of day of year and irrigation treatment (LYS = lysimeter; 40–SDI = 1 m (40 inch) lateral spacing subsurface drip; 80–SDI = 2 m (80 inch) lateral spacing subsurface drip; FURR = furrow irrigation).

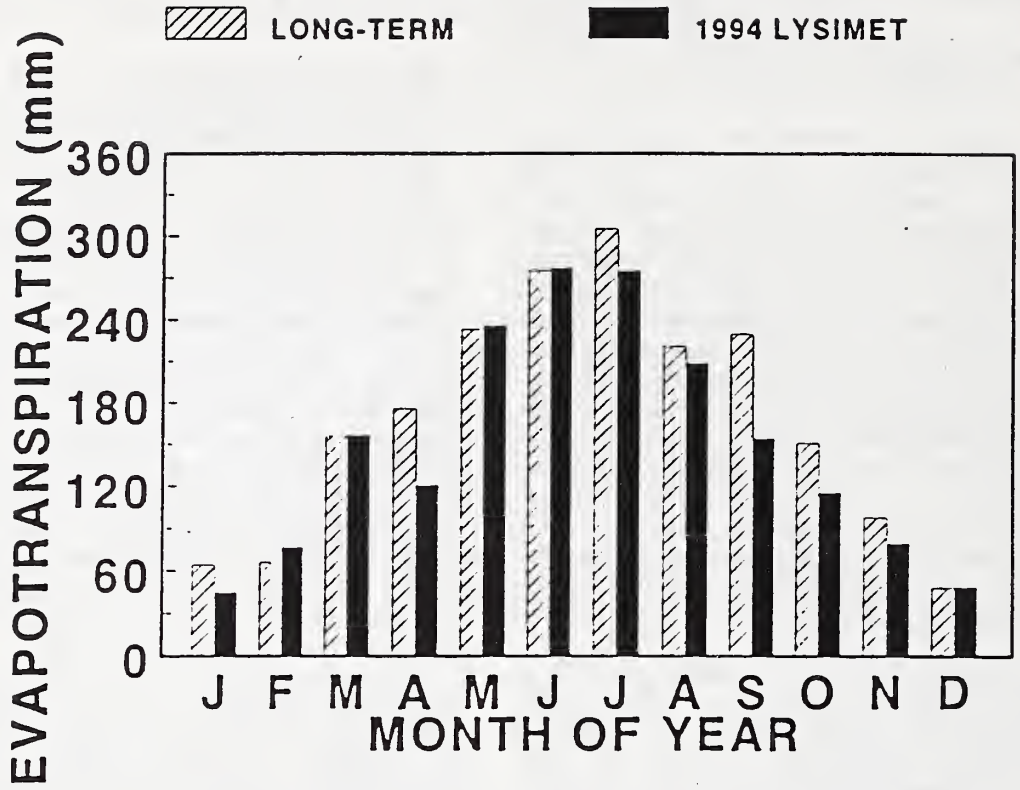


Figure 2. Monthly crop lysimeter evapotranspiration for long-term furrow-irrigated alfalfa at the Brawley site (B. Meek, B. LeMert et al.) during 1968 to 1974 compared to 1994 lysimeter values under subsurface drip irrigation in current experiment.

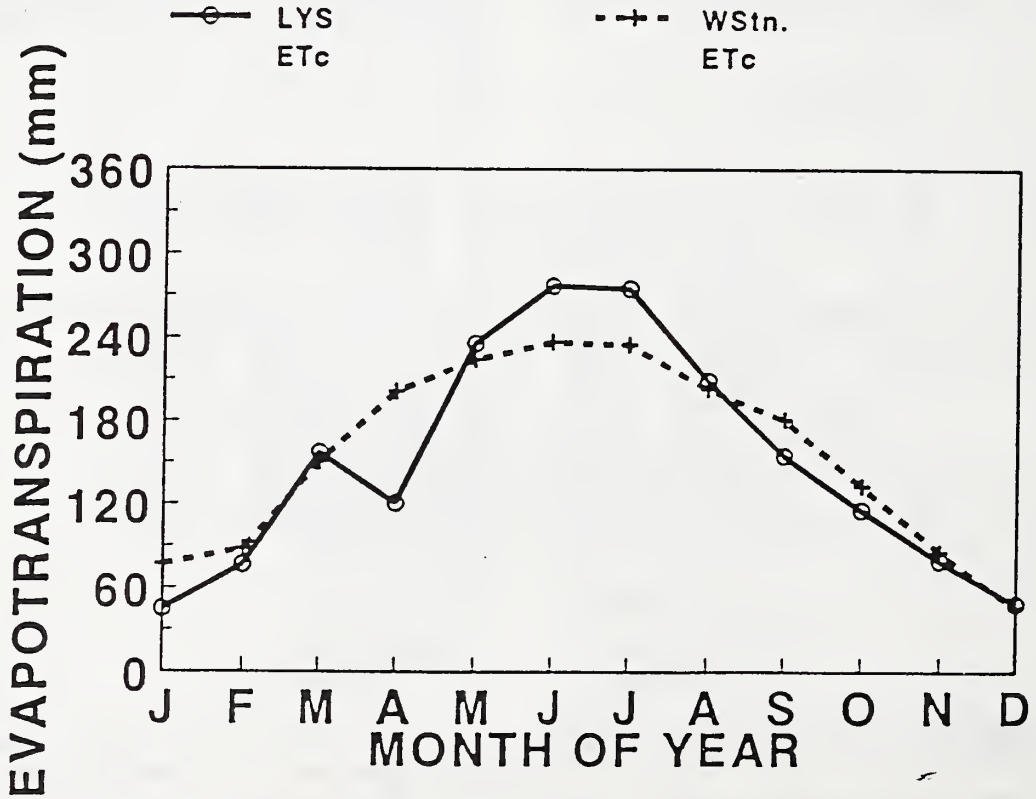


Figure 3. 1994 Monthly evapotranspiration of the lysimeter compared to evapotranspiration calculated using 1994 CIMIS weather station reference evapotranspiration and alfalfa crop coefficient determined using Brawley lysimeter.

MANAGEMENT OF SUBSURFACE DRIP AND FURROW IRRIGATION FOR FORAGE ALFALFA IN THE IMPERIAL VALLEY: II. PLANT WATER STATUS AND SOIL SALINITY PROFILES, SYSTEM MAINTENANCE

R.B. Hutmacher, R.M. Mead, D.A. Clark, M.S. Peters, R. Swain, P. J. Shouse, M. van Genuchten, S.S. Vail, C.A. Hawk, T Donovan, J. Jobes, J. Fargerlund, R. Kershaw, D. Currie

OBJECTIVES: The alfalfa subsurface drip/furrow irrigation experiment is a five-year evaluation of alfalfa water requirements and the long-term influence of irrigation management on soil accumulations of salt and potentially yield-limiting specific ions. This project focuses on the comparison of crop responses, irrigation water requirements and salt accumulation as affected by subsurface drip (SDI) versus furrow irrigation. In addition, the influence of two drip tubing types and two lateral spacings (1.02 m vs. 2.04 m) are being evaluated.

PROCEDURES: Operational procedures were as detailed in a prior report in this volume entitled "Management of Subsurface Drip and Furrow Irrigation for Forage Alfalfa in the Imperial Valley: I. Operational Procedures, Water Applications, Evapotranspiration".

The irrigation water used in this study was from the Colorado River canal system, with an average electrical conductivity (EC) of 1.15 dS m^{-1}, pH of 7.4 to 7.7, bicarbonate concentration of 2.2 to 2.7 mmol L^{-1} and chloride concentration of 2.5 to 3.6 meq L^{-1}. Soil salinity was monitored on soil samples collected either with hand augers or with a tractor-mounted hydraulic core sampler, with samples taken at 15 to 30 cm increments in a grid pattern.

RESULTS AND DISCUSSION: *Plant Water Status, Rooting Depth.* Infrared thermometer data (used to determine "Crop Water Stress Index" values) was collected to evaluate plant water status during several periods in 1994. This data indicated that plant water stress was significantly less in SDI than in furrow irrigated plants during the 5 to 7 days prior to harvest and the early re-growth period (data not shown). Water stress levels in the SDI plots were also significantly less than during comparable pre- and post-harvest periods during the 1992 alfalfa season (when SDI had to be cut back during the harvest period to avoid surface soil wet areas). Plant regrowth (measured as canopy days) following cutting in the SDI plants was faster than in furrow-irrigated plants (data not shown). Additional data will be collected in 1995 to further quantify differences in rate of regrowth and relative levels of plant water stress occurring across irrigation treatments.

During Phase I of this experiment, downward water movement with furrow and SDI was largely confined to the upper 75 to 90 cm (2.5 to 3 feet) of the soil, with most of the root system confined to the upper 90 cm (data not shown). During Phase II, the same pattern of water use is evident in furrow plots; however, with the deeper drip installation, soil water use (monitored with neutron attenuation techniques) and depth of root activity (evaluated as presence of live roots in soil samples) has been shifted to the 45 cm to 120 cm (1.5 to 4 foot) depth, with a much drier upper soil zone (15 to 22 cm or 6 to 9 inch depth) (data not shown).

Soil Salinity Profile Development under Drip vs. Furrow Irrigation. Accumulations of salt within the root zone of alfalfa can be a significant problem, since alfalfa has a threshold salinity level of 2.0 dS m^{-1} (root zone soil saturation extract salinity level associated with the beginning of yield reductions). In Phase I, concentrations of salinity in the 15 cm to 90 cm (0.5 to 3 feet) depths in the soil profile largely remained in the range of 1.7 to 2.6 dS m^{-1}. However, salinity levels exceeded 4 to 4.5 dS m^{-1} in some portions of the beds and furrows where there was little soil water movement and leaching was limited (data not shown).

In Phase I, some areas of the surface 15 cm (6 inches) of soil in the drip plots had

salinity levels in excess of 3 to 4.5 dS m^{-1}, presumably due to movement of water and salts up to the soil surface. Even these high concentrations of salts did not result in stunted plants, perhaps due to limited root activity in the upper parts of the soil profile. However, these surface concentrations of salt do represent a potential threat if flushed down into the active root zone by rain or if too small an amount of water is applied for leaching salts below the root zone.

In general, locations and amount of salt accumulation across the beds in Phase I depended on lateral spacing and whether or not the wetted patterns from adjacent beds met. In the 1.02 m (40 inch) drip lateral spacing treatments, the highest salt accumulations were between the beds, with lateral water movement from adjacent beds meeting and depositing the most salt in the furrow. In the 1.02 m furrow plots, the highest salt accumulations were found in the center of the beds due to lateral movement from adjacent furrow. In the 2.04 m (80 inch) drip lateral spacing treatments, the highest salt accumulations were 15 to 45 cm deep and under the outer plant rows at the edge of the beds.

Much of this within-bed variation and stratification in salinity levels developed during Phase I was eliminated with the large pre-plant water application (200 to 250 mm of water) in late-spring of 1993 (after installation of the new drip tubing and prior to sudan grass planting). For Phase II, soil samples were taken in the fall of 1993, June of 1994 and January of 1995 to evaluate salinity distribution as affected by location within the bed and irrigation method, but the results have not yet been compiled.

System Operation and Maintenance Related to Water Quality. There have been no problems with excessive emitter flow rate or root intrusion into the drip lines during Phase II. We should note that the lack of root intrusion problems in this study is under the following operating conditions: (1) use of "RAM" drip tubing or "Rootguard" drip tubing, both of which have turbulent-flow emitters and thick walls when compared with tapes; (2) continuous injection of a 5 to 7 percent phosphoric acid solution to maintain a concentration of 10 to 20 mg/L; and (3) weekly injection of chlorine (free chlorine level of 5 to 10 mg/L) and N-phuric acid (to bring the pH down to about 3.5) for a duration of about 1 to 2 hours per week. There is no firm evidence that root intrusion would occur if the chemical treatments were not used, but to prevent chemical precipitate clogging, acid treatments are most likely a necessity.

FUTURE PLANS: For a total profile salinity evaluation, soil samples will be collected again in fall of 1995. At two month intervals during 1995, however, soil samples will be collected at 15 cm increments to a depth of 60 cm at three bed positions (center of bed, under outer plant row, at outer edge of bed) to monitor changes in soil salinity during the current growing season. Goals of this data collection will be to gather information to assess whether sprinkler water applications for salt leaching should be done on an annual or biannual basis.

MANAGEMENT OF SUBSURFACE DRIP AND FURROW IRRIGATION FOR FORAGE ALFALFA IN THE IMPERIAL VALLEY: III. CROP GROWTH, YIELD, FORAGE QUALITY, INSECT PROBLEMS

R.B. Hutmacher, R.M. Mead, D.A. Clark, M.S. Peters, R. Swain, P. J. Shouse, M. van Genuchten, S.S. Vail, C.A. Hawk, T Donovan, J. Jobes, J. Fargerlund, R. Kershaw, D. Currie

OBJECTIVES: The alfalfa subsurface drip/furrow irrigation experiment is a five-year evaluation of alfalfa water requirements and the long-term influence of irrigation management on soil accumulations of salt and potentially yield-limiting specific ions. This project focuses on the comparison of crop responses, irrigation water requirements and salt accumulation as affected by subsurface drip (SDI) versus furrow irrigation. In addition, the influence of two drip tubing types and two lateral spacings (1.20 m vs. 2.04 m) are being evaluated.

PROCEDURES: Operational procedures were as detailed in a prior report in this volume entitled "Management of Subsurface Drip and Furrow Irrigation for Forage Alfalfa in the Imperial Valley: II. Operational Procedures, Water Applications, Evapotranspiration".

All alfalfa harvests were done using a commercial-type swather, rake and baler. Harvest results are based on the total plot area, with all bales counted, individually weighed in the field, and corrected to equivalent water content. Forage quality evaluations were conducted at several commercial laboratories using State of CA commercially-accepted procedures.

RESULTS AND DISCUSSION: *Crop Establishment and Forage Yields.* Through the winter of 1994, the alfalfa crop establishment has been very successful, with excellent plant stands. Although water applications and crop water use were quite similar in the furrow and SDI plots through December of 1994, yields were significantly higher (average of 36 percent) in the SDI plots (Fig. 1). Forage yields were not significantly affected by type of drip tubing. There was a trend toward higher forage yields in the 2.04 m (80 inch) lateral spacing treatments when compared with 1.02 m (40 inch) spacing, but the differences were not always significant (Fig. 1). Harvest dates across all irrigation treatments have not varied by more than 3 to 4 days. The total number of harvests have been identical in all treatments.

Since 1994 was the crop establishment year, harvests did not start until March and there were fewer total harvests than will occur in subsequent years. It will be important to continue measurements in this field for at least one additional year to see if this yield advantage under drip continues. During Phase I of this experiment, the yield advantage under SDI was greater in the first year than in the second harvest year. Even though water use between SDI and furrow irrigated plots was similar in 1994, the substantially higher yields under SDI represent a 30 to 40 percent increase in water use efficiency (yield per unit water used).

Hay has been sampled from representative bales in all treatments during selected harvests at different times of the year, with samples sent to a commercial laboratory for analysis of components of forage quality. In terms of protein, crude fiber and TDN parameters, preliminary results indicate a significant improvement in quality of spring and fall crops by several quality parameters (in 1992 and 1994) under SDI (data not shown). A more rigorous sampling will be done in 1995, involving larger samples and several commercial laboratories in order to verify any significant differences in forage quality due to irrigation method.

Insect Problems and Relationship to Irrigation Method. During the late summer of 1994, a significant problem with cutworms resulted in severe damage to regrowth. The damage occurred over a long time period and affected the SDI plots more

seriously than the furrow irrigated plots. University of California and pesticide industry representatives suggested that use of furrow irrigation results in a routine flooding of soil cracks which the cutworms retreat to during the warmest parts of the day. This flooding both drowns some of the cutworms and floats others up to the surface where afternoon conditions are not good for their survival. Because this flooding does not occur in SDI plots, it was thought that worm populations could increase to the point where they were a threat to both regrowth and stand survival. To limit cutworm damage, two spray pesticide applications were made about 7 days apart after sunset, when the worms come up above the soil surface to feed.

There have been repeated problems with other insects such as flea beetles, aphids and some white fly damage during the fall months (mostly related to secondary fungus development on honeydew). Some of these infestations have required pesticide applications. In these other insect infestations, problems have not appeared to be significantly influenced by irrigation method.

FUTURE PLANS: Plans for 1995 are described in previous parts of this report. In addition, more intensive measurements of the rate of plant regrowth (height, dry matter) will be made during 1995 to quantify treatment effects on the rate of growth during each harvest cycle. This information will be used to determine factors most responsible for yield increases with subsurface drip irrigation.

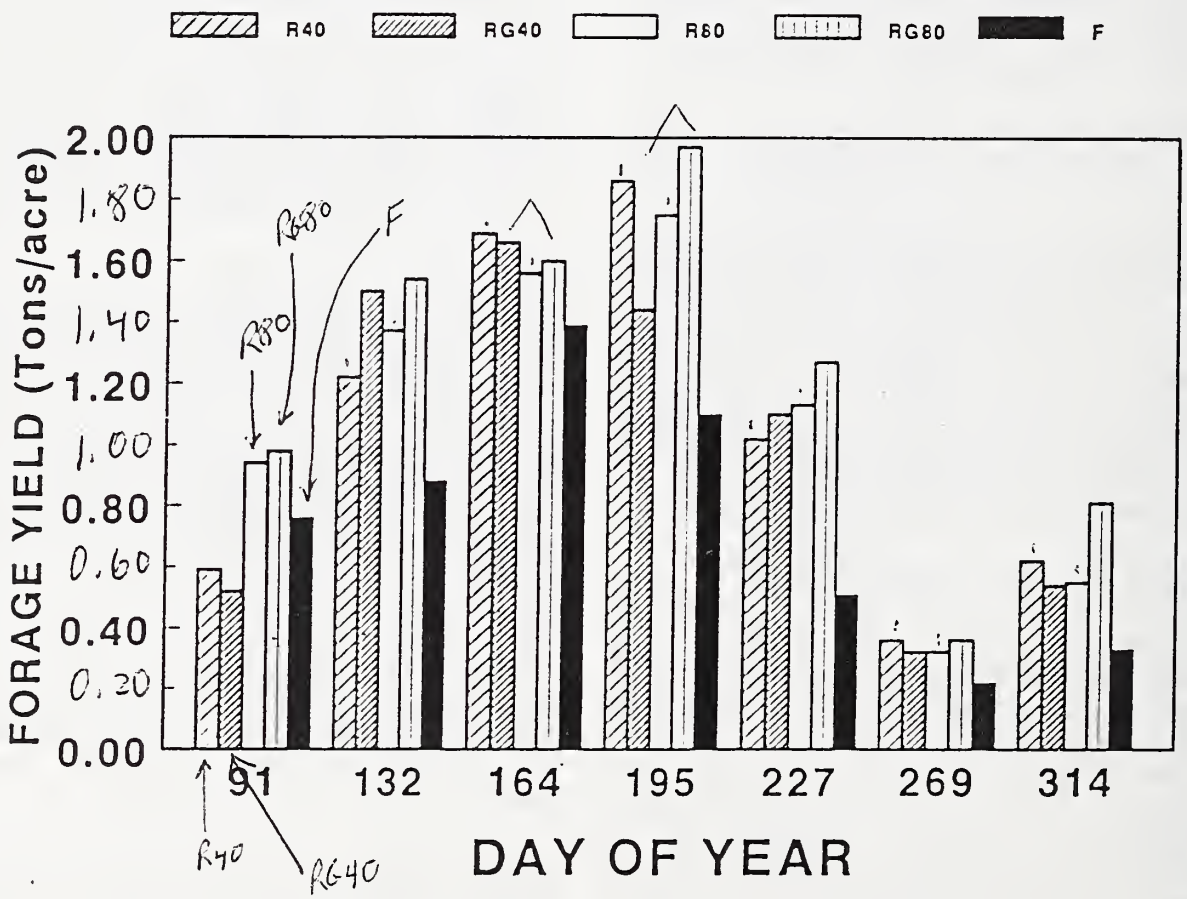


Figure 1. Forage alfalfa yields (in tons per acre) for individual harvests in 1994 as a function of day of year and irrigation treatments (R40 = "RAM" drip tubing, 40 inch (1.02 m) lateral spacing; RG40 = "Rootguard" drip tubing, 40 inch (1.02 m) lateral spacing; R80 = "RAM" drip tubing, 80 inch (2.04 m) lateral spacing; RG80 = "Rootguard" drip tubing, 80 inch (2.04 m) lateral spacing; F = furrow irrigated).

UPTAKE OF SE BY FOUR PLANT SPECIES GROWN UNDER INCREASING SALT-REGIMES IN THE SOIL

G.S.Bañuelos, N. Terry, A. Zayed, B. Mackey,
L. Wu, C. Cook, S.Akohoue, and S. Zambrzuski

OBJECTIVE: To evaluate the efficiency of soil Se removal by selected cultivars of Indian mustard, kenaf, tall fescue, and birdsfoot trefoil grown under increasing soil salinity levels.

PROCEDURE: Four plant cultivars were evaluated under greenhouse conditions for salt tolerance, Se uptake, and their ability to lower soil Se. The four plant cultivars used were the following: canola (*Brassica napus* c. Horizon), kenaf (*Hibiscus cannabinus* L. cv. KU 3876), tall fescue (*Festuca arundincea* L. cv. Alta), and birdsfoot trefoil (*Lotus tenuis* Hmb.). The experiment design was a randomized complete block with four soil salinity treatments (EC) of <1, 5, 10, 20 dS m^{-1}, four plant species, six pots per treatment for each species.

Eighteen liter growing pots were filled with 10 kg of a Hanford sandy loam soil. The salt solution treatments were constructed with NaCl and CaCl, on approximately 5:1 ratio by weight in a 100 liter solution for each respective salt treatment. Designated pots for each salt treatment were placed in a plastic container containing the respective 100 liter salt solution treatment. After 36 hours of placement in salt solution the pots were removed and allowed to drain for 24 hours. The pots were then allowed to air dry until they had reached approximately 60% field capacity, at which time they were covered to prevent further soil evaporation. Each pot was then emptied into a container and Se as Na_2SeO_4 was sprayed onto the soil and mixed until a concentration of 2 mg Se kg^{-1} had been reached. This process was repeated for each salt treatment.

Seeds from each cultivar of the four plant species were sown into each pot. The selection of plant species was based on results collected from salt tolerance experiments conducted by Zayed and Terry, 1994 (unpublished). Plants were grown under greenhouse conditions (described elsewhere in Ann. Rpt., *Response of cotton and kenaf irrigated with 'B-amended water'*) and watered when water loss was estimated to fall to approximately 55% to 65% field capacity.

Ninety days after planting, all plant species were harvested and divided up into shoots and roots, and oven dried at 50°C for seven days. Plant parts were then ground in a stainless steel Wiley mill. Soil from each harvested pot was mixed and 500 g soil sample was taken and oven-dried for seven days. Both plant and soil samples were prepared, wet acid digested, and analyzed for Se. Soil EC was determined from a saturated soil paste. Selenium was analyzed using an atomic absorption spectrophotometry with continuous hydride generation. Replicated plant samples were dry ashed at 500°C and Ca, Mg, and Na were determined by inductively coupled plasma and Cl was determined by titrimetry.

RESULTS: Germination and emergence rates of all species were visually delayed with increasing salinity levels. Any evidence of delayed growth diminished, however, as the plants progressively matured. Preliminary final shoot and root yields from each species grown at 5 or 10 dS m^{-1} were generally not significantly different from the same species grown under 'control conditions'. However, significant differences were observed for all species, especially kenaf, at the high salt treatment (20 dS m^{-1}) when compared to the control. Concentration of Ca, Na, and Cl increased with increasing salinity levels for all plant species (Table 1 and 2). Canola accumulated the highest concentration of all selected ion including Se in this study.

Total concentrations of soil Se remaining in the soils after harvest were generally lower for all species, especially in soils supporting canola. Percentage differences between preplant and postharvest soil Se concentrations during the course of this

study indicate that canola was potentially effective in lowering Se levels in these Se-enriched soils (analyses are presently being conducted).

FUTURE PLANS: Continue processing data and complete soil analyses. Based on final results, a field study will be conducted with the best-perfoming plant species in saline soils.

Table 1. Elemental concentrations of above-ground dry material from four plant species grown in Se-enriched soil at different salinity levels.†

Crop	Salinity EC (dS m^{-1})	Shoot concentrations of: Se (mg kg^{-1} DM)	Ca (%)	Na (%)	Mg (%)	Cl (%)
Canola‡	K°§	250(8)	0.99(.17)	0.20(.01)	0.34(.01)	0.19(.01)
	5	315(11)	2.01(.20)	0.78(.06)	0.58(.03)	0.24(.01)
	10	260(15)	2.12(.25)	1.12(.12)	0.59(.03)	0.29(.02)
	20	225(10)	1.98(.25)	1.48(.06)	0.60(.04)	0.71(.14)
Kenaf‡	K°	92(6)	0.99(.04)	0.03(.00)	0.42(.02)	0.15(.02)
	5	87(5)	1.23(.03)	0.07(.01)	0.51(.03)	0.42(.06)
	10	78(9)	2.12(.03)	0.13(.03)	0.83(.10)	0.60(.02)
	20	50(4)	2.85(.03)	0.35(.05)	1.20(.10)	1.11(.19)
Tall fescue¶	K°	35(3)	0.24(.00)	0.26(.01)	0.35(.00)	0.19(.01)
	5	33(1)	0.26(.02)	0.40(.01)	0.34(.00)	0.35(.06)
	10	28(1)	0.28(.00)	0.60(.01)	0.36(.00)	0.37(.05)
	20	24(2)	0.31(.00)	0.79(.01)	0.39(.00)	0.38(.01)
Birdsfoot trefoil¶	K°	130(17)	1.99(.16)	0.29(.08)	0.52(.01)	0.13(.00)
	5	101(12)	0.78(.03)	0.27(.01)	0.29(.01)	0.27(.02)
	10	100(10)	0.82(.04)	0.52(.01)	0.35(.01)	0.47(.06)
	20	89(17)	0.81(.05)	0.79(.04)	0.32(.01)	0.64(.06)

†Values are the mean from six replications (each comprised of 8 plants, respectively) followed by the standard error in parenthesis.

‡Leaves only.

§K° Represents control soil (<1 dS m^{-1}).

¶Mean is presented from three clippings.

Table 2. Elemental concentrations of roots from four plant species grown in Se-enriched soil at different salinity levels.†

Crop	Salinity EC (dS m^{-1})	Root concentrations of: Se (mg kg^{-1} DM)	Ca	Na	Mg	Cl
			(%)			
Canola	K°‡	80(5)	0.61(.02)	0.66(.02)	0.28(.02)	0.05(.00)
	5	75(7)	0.64(.02)	2.65(.10)	0.30(.02)	0.74(.06)
	10	62(8)	0.77(.04)	2.93(.08)	0.33(.01)	1.38(.04)
	20	60(7)	0.87(.01)	3.14(.06)	0.77(.03)	1.76(.04)
Kenaf	K°	33(2)	0.50(.02)	0.36(.01)	0.61(.03)	0.12(.03)
	5	30(2)	0.58(.04)	0.48(.05)	0.62(.01)	0.30(.04)
	10	26(2)	0.61(.04)	0.60(.02)	0.70(.02)	0.41(.06)
	20	24(3)	0.68(.05)	0.91(.04)	0.77(.03)	0.70(.07)
Tall fescue§	K°	11(3)	0.57(.05)	0.23(.05)	0.30(.01)	0.08(.00)
	5	10(2)	0.60(.03)	0.28(.04)	0.31(.01)	0.11(.00)
	10	8(1)	0.64(.05)	0.38(.04)	0.33(.02)	0.12(.00)
	20	7(1)	0.68(.06)	0.60(.06)	0.37(.01)	0.16(.03)
Birdsfoot trefoil§	K°	50(5)	0.44(.01)	0.15(.01)	0.23(.01)	0.07(.00)
	5	80(5)	0.19(.02)	0.18(.01)	0.25(.01)	0.14(.01)
	10	82(6)	0.20(.01)	0.30(.00)	0.26(.00)	0.20(.01)
	20	62(3)	0.20(.01)	0.39(.01)	0.28(.01)	0.24(.02)

†Values are the mean from six replications (each comprised of 8 plants, respectively) followed by the standard error in parenthesis.

‡K^0represents control soil (<1 dS m^{-1}).

§Mean is presented from three clippings.

EVALUATION OF DIFFERENT PLANT SPECIES USED FOR BIOREMEDIATION OF SELENIUM-CONTAMINATED SOIL FROM KESTERSON RESERVOIR

G.S. Bañuelos, L. Wu, B. Mackey, C. Cook, N. Terry,
A. Zayd, S. Akohoue, and S. Zambruzuski

OBJECTIVE: To evaluate the ability of kenaf, canola, and tall fescue to grow in Se-laden soil collected from Kesterson Reservoir and determine the efficiency by which each plant species tolerates and lowers the total Se content of the soil under greenhouse conditions.

PROCEDURE: A one year greenhouse pot study was conducted to determine Se and B uptake, salt tolerance, and soil Se removal by three plant species planted in soil sediment collected from Kesterson Reservoir. These species include canola (*Brassica napus* cv. Westar), kenaf (*Hibiscus cannabinus* L. cv. Indian), and tall fescue (*Festuca arundincea* L. cv. Alta). The experimental design was a randomized block with four treatments: canola, kenaf, tall fescue, and bare pots (without plants), with 18 pots per treatment, respectively. There was a total of three plantings for canola (designated as I, II, III), two for kenaf (designated as I, II), and one for tall fescue (which were clipped four times; designated as I, II, III, IV). Each harvested species (canola and kenaf) was respectively replanted in the same soil from the previous planting. Tall fescue - grew in the same pots without replanting. The planting schedule resembled the suggested number of plantings for each of the species during the course of a year under normal field conditions. Eighteen liter growing pots were filled with 10 kg air-dried soil collected as sediment from Kesterson Reservoir in central California. Soil was mixed thoroughly by a mechanical mixer, passed through a 5 mm mesh, and preplant soil samples were taken. The soil in each pot was brought to field capacity with the addition of water, allowed to air dry and weighed daily until approximately 60% field capacity had been attained. Seeds from the three plant species were sown into respective pots (top layered with 100 g of vermiculite potting mixture). After 7 to 10 d, pots containing canola and kenaf were thinned to the four healthiest plants, while tall fescue was thinned to approximately 2 cm plant spacing. The greenhouse temperatures were maintained at 24±2°C and 21±2°C day/night regime. All pots were irrigated when the soil water loss was estimated by weight to be approximately 55% to 65% field capacity. Drainage was minimized and did not exceed 15% based upon soil SO_4 differences in the soil at preplant and at harvest.

Seventy-five days after first emergence, canola I was harvested 2 cm above the soil surface, tall fescue I was clipped 5 cm above the soil surface and kenaf I was allowed to continue growing. Complete harvested plants were separated into shoots and roots (i.e., canola), washed free of soil with deionized water, oven-dried at 50°C for 7 d, weighed and ground in a stainless steel Wiley mill. This procedure for preliminary tissue preparation was followed for all subsequent harvests and clippings of the three plant species. Soil from each harvested pot was thoroughly mixed, root residues were removed and approximately 500 g soil sample was collected from each pot before replanting to the harvested plant species. Soil samples were also taken in the same manner from 'control pots'. Canola I pots were then replanted to canola II and tall fescue I and kenaf I were allowed to continue growing. Seventy-five days after emergence of canola II, canola II was harvested, tall fescue II was clipped, and kenaf I was harvested 2 cm above the soil surface. Soil samples were collected from pots of canola II, from kenaf I, and from 'control soils'. Canola II pots were replanted to canola III, kenaf I pots were replanted to kenaf II, and tall fescue II was allowed to continue growing. Seventy-five days after emergence of the third planting of canola, canola III was harvested, tall fescue III was clipped and kenaf II and tall fescue III were allowed to continue growing for another forty-five days.

After final harvest of kenaf II and tall fescue IV, pots from each treatment were

emptied, mixed, and final soil samples collected. Both plant and soil samples were prepared, wet acid digested, and analyzed for Se and B. Soil EC was determined from a saturated soil paste. Selenium was analyzed by atomic absorption spectrophotometry with continuous hydride generation and B by inductive coupled plasma spectrophotometry.

RESULTS: Preliminary results on tissue Se and B accumulation for all the species are shown in Table 1. Canola accumulated the greatest amount of Se, while kenaf accumulated the greatest amount of B. Preliminary results from the soil data in Figures 1a-h indicate that the planting of canola lowered the total soil Se to the greatest extent.

FUTURE PLANS: Continue processing the soil and plant analyses. After final evaluation a field study is planned for Kesterson Reservoir. A manuscript will be prepared.

Table 1. Preliminary data on the accumulation of Se and B and of different plant species grown in Kesterson soil†.

Species	Planting	Clipping	Se Concentration In: Shoots (mg kg^{-1} DM)	Se Concentration In: Roots (mg kg^{-1} DM)	B Concentration In: Shoots (mg kg^{-1} DM)	B Concentration In: Roots (mg kg^{-1} DM)
Canola	I	NA	470(22)	44(2)	180(3)	33(0.6)
	II	NA	280(10)	25(3)	106(7)	18(0.9)
	III	NA	—	—	—	—
	Control‡	NA	<1(0.03)	<0.5(0.01)	12(0.1)	10(0.2)
Kenaf	I	NA	45(0.5)	60(8)	425(14)	30(0.9)
	II	NA	—	—	—	—
	Control‡	NA	<0.2(0.1)	—	—	—
Tall fescue	I	I	50(2)	NA	111(6)	NA
	NA	II	37(1)	NA	117(10)	NA
	NA	III	17(2)	NA	65(7)	NA
	NA	IV	10(0.4)	NA	37(2)	NA
	Control‡		<0.5(0.0)	—	9(3)	10(3)

†Values are the mean from 18 replications with the standard error in parenthesis.

‡Values for 'controls' consist of means from all plantings for each species grown in non-seleniferous soils.

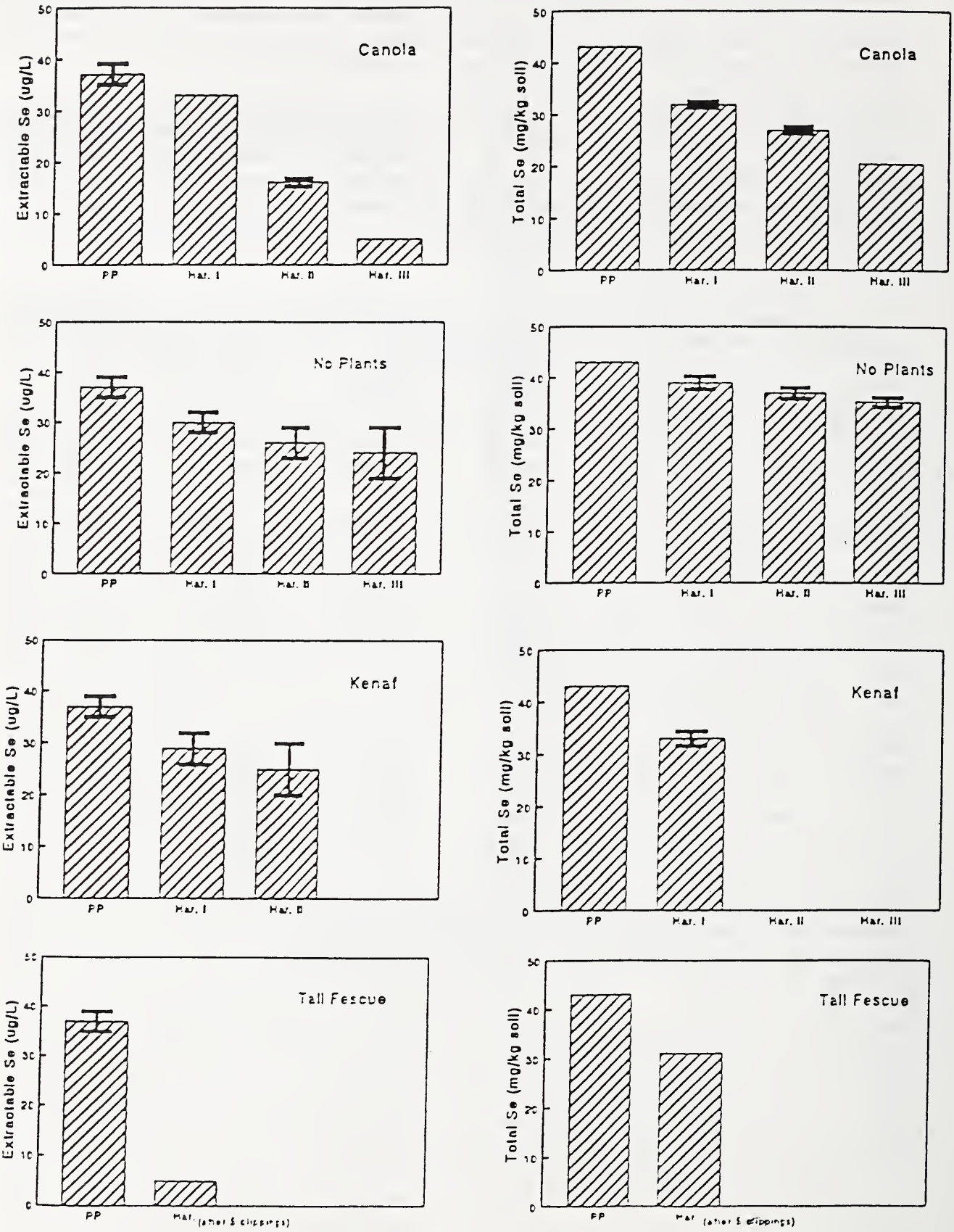


Figure 1. Differences of soil Se at preplant and after multiple harvests of different plant species grown in Kesterson soil.

EVALUATE THE EFFECT OF CROP ROTATION ON MANAGING BORON AND SELENIUM LEVELS IN POOR QUALITY SOILS

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OBJECTIVES: To determine the extent to which crop rotation with selected B-tolerant species contributes to the reduction of soil B levels.

PROCEDURE: A multiple year crop rotation study with *Brassica juncea* (Indian mustard), *Festuca arundincea* (tall fescue), *Lotus corniculatus* (birdsfoot trefoil), *Hibiscus cannabinus* (kenaf), and bare plots (control plots) is being conducted on Three Way Farms near Los Banos, California. The treatment design was a complete randomized design with each treatment replicated a minimum of three times on 10 x 10 m plots. The five treatments for three years consisted of the following plant species planted in crop rotation for three years:

Trt. *I*: 1st year (Indian mustard),
2nd year (Indian mustard),
3rd year (tall fescue),
4th year (tall fescue).

Trt. *II*: 1st year (tall fescue),
2nd year (tall fescue),
3rd year (tall fescue),
4th year (tall fescue).

Trt. *III*: 1st year (kenaf),
2nd year (kenaf),
3rd year (tall fescue),
4th year (tall fescue).

Trt. *IV*: 1st year (kenaf),
2nd year (birdsfoot trefoil),
3rd year (birdsfoot trefoil),
4th year (birdsfoot trefoil).

Trt. *V*: 1st year (bare plot),
2nd year (bare plot),
3rd year (bare plot),
4th year (bare plot).

Soil samples were taken from each plot as already described (Ann. Rpt., 1993; *Comparison of Wet Acid Digestion by Microwave or Block Digestor on the Recovery of Selenium and Boron in Plant Samples*) during the designated growing season between May 1 (preplant) and October 15 (harvest) of each year. Treatments were sprinkle-irrigated based on data accumulated by CIMIS and weekly neutron probe readings taken in two locations on each plot. Plant samples of each species were hand-clipped from four one meter square sampling sites within each plot for each treatment. Both plant and soil samples were prepared and analyzed for Se and B as already described (Ann. Rpt., 1993; *Comparison of Wet Acid Digestion by Microwave or Block Digestor on the Recovery of Selenium and Boron in Plant Samples*).

RESULTS: Preliminary data for soil samples the first three years are shown in Table 1. For the first three years (Treatment 1) the planting of *B. juncea*, *B. juncea*, and tall fescue appears to be the most effective crop rotation in lowering soil extractable B and total soil Se. In comparison to bare plots, however, all crop rotations (Treatments I-IV) lowered levels of both extractable B and total Se in the soil.

FUTURE PLANS: The study will be completed in 1995. Future studies will include incorporating generally planted agronomic crops in westside soils of central California, i.e., alfalfa, cotton, tomatoes, in crop rotation with the above treatments to lower soil B and Se. Moreover, deeper depths of the soil profile will be analyzed for soil Se and B after the perennial species are eventually growing in all treatments. A manuscript will be prepared and submitted in 1995.

Table 1. Mean preplant and postharvest soil concentrations of extractable B and total Se between 0 to 75 cm for different crop rotations during 1992–1994.†

Treatment‡ (#)	Plant species	Extractable B		Total Se	
		Preplant	Harvest	Preplant	Harvest
		(mg L^{-1})		(mg kg^{-1} soil)	
1992					
I	*B. juncea*	7.0	4.8	1.10	0.75
II	*F. arundincea*	6.6	5.4	0.98	0.84
III	*H. cannabinus*	6.8	5.1	1.20	0.98
IV	*H. cannabinus*	5.4	4.3	0.96	0.82
V	Bare plot	6.2	5.8	1.20	1.13
1993					
I	*B. juncea*	5.1	4.4	0.82	0.68
II	*F. arundincea*	5.0	4.2	0.91	0.78
III	*H. cannabinus*	4.7	4.1	1.04	0.83
IV	*L. corniculatus*	4.6	4.3	0.79	0.64
V	Bare plot	5.6	5.4	1.17	1.13
1994					
I	*F. arundincea*	4.0	3.2	0.62	0.55
II	*F. arundincea*	3.8	3.3	0.75	0.66
III	*F. arundincea*	4.3	3.9	0.84	0.76
IV	*L. corniculatus*	4.0	3.0	0.78	0.65
V	Bare plot	5.5	5.2	1.09	1.06
1995					
I	*F. arundincea*	NA	NA	NA	NA
II	*F. arundincea*	"	"	"	"
III	*F. arundincea*	"	"	"	"
IV	*L. corniculatus*	"	"	"	"
V	Bare plot	"	"	"	"

†Values presented represent the means from a minimum of 36 soil samples taken from 0–75 cm in the soil.

‡Each treatment number represents three replicates.

NA Not applicable; currently growing in 1995.

ENHANCING THE BIOLOGICAL VOLATILIZATION OF SELENIUM BY *BRASSICA SPP.*

N. Terry, A. Zayd, and G.S. Bañuelos

OBJECTIVE: Test the effect of different vegetation management practices on enhancing the removal of Se from soils by biological volatilization of Se.

PROCEDURE: *Brassica juncea czern* L. was grown in a temperature-controled greenhouse using a 21°C and 18°C day/night temperature regime and having a minimum average photon flux density of 850 μmol m^{-2} s^{-1}. After germination, seedlings were transplanted in groups of ten into 20-L growing pots filled with 15 kg of Panoche clay loam, [fine-loamy, mixed (calcareous), thermic Typic Torriorthents) (passed through a 5 mm mesh) taken from the west side of the San Joaquin Valley in central California. In some areas, this soil is known to have a naturally high concentration of total Se (>1.5 mg Se kg^{-1} soil) and an EC > 5 dS m^{-1} (from a saturation extract). Five treatments were applied as follows (the term "disking" used below is taken from and relates to the agronomic practice; however, in the greenhouse experiment, "disking" means that the plant material will be harvested, chopped, and incorporated into potted soil [all plants were grown for a total of 75 days in Se-laden soil]):

1. Control: Plants were grown for 75 days and harvested only once at the end of the growing season.

2. One clipping: Plants were cut 10 cm above soil surface after 25 d of growth and harvested after 75 days.

3. Two clippings: Plants were clipped twice at 25-day intervals and harvested after 75 days.

4. One disking: Plant were grown for 25 days, harvested, and disked into the soil. Another crop of *B. juncea* was planted in this soil immediately after disking in the old crop and allowed to grow for the rest of the growing season.

5. Two diskings: Plant shoots were harvested and disked into the soil after 25 days of growth. After each disking (a total of two) a third crop of *B. juncea* was planted and the final crop will be harvested at the end of the growing season.

The experimental design was a complete randomized block with each treatment replicated five times. Selenium volatilization was monitored from all treatments as well as from bare soil. Selenium concentrations were measured in the soil before planting and at the end of the experiment and in removed shoots and remaining root for all treatments.

The rate of Se volatilization was determined by measuring the amount of volatile Se given off from a plant mounted in a collection chamber housed within a plant growth chamber. Plants were grown in 2 l containers containing 0.25 strength Hoagland's solution and 20 μM Se. Air from the collection chamber was passed through an alkaline peroxide trap that oxidized the volatile Se into a form suitable for later measurement (see below). The collection chamber consisted of a 76 cm long Plexiglas cylinder, 28 cm in diam. (volume = 46.7 L). Rapid air movement within the chamber was promoted using a small fan (to improve mixing and to minimize the boundary layer over the leaf surface). Air entered the chamber with the aeration of the culture solution; sufficient vacuum was applied by a water aspirator to induce a slight negative pressure (about -100 Pa) in the collection chamber, generating approximately two air changes per hour.

Selenium volatilization was measured for each chamber using a single trap and a collection period of 7 h. Subsequently, three alkaline-peroxide traps were used (in series) and the collection period was extended to 24 h (including the regular 8-h dark period). A statistical analysis of the data showed that there was no significant difference between the two collection procedures. The data were therefore combined and regarded as three replicates. The alkaline-peroxide trap consisted of 200

mL of trapping solution (160 mL of 0.05 *M* NaOH + 40 mL of 30% H_2O_2) in a 500-mL gas washing bottle (Corning 31760C). To analyze Se from the trap, a 5-mL sample was boiled for 30 min (to remove residual H_2O_2) and cooled. Five milliliters of concentrated HCl were added to the boiled sample (final concen-tration 6 *M* HCl), boiled for an additional 10 min, allowed to cool, and made up to 10 mL with distilled H_2O. Total Se was then measured in the sample using an atomic absorption spectroscopy with hydride generation according to Varian's proce-dure for the VGA-72 vapor generator.

After determining Se volatilization rates, each plant was removed from the collection chamber, separated into roots, stems (or, in some species, shoot tissue other than leaf blades), and leaves and leaf area per plant was determined using a Delta-T devices leaf area meter. After drying at 60°C for 24 to 48 h, plant tissue samples were acid digested and analyzed by the atomic absorption with hydride generation method.

RESULTS: Samples are presently being analyzed for Se.

FUTURE PLANS: Plant *B. juncea* in Se-laden soils and measure the rates of vola-tile Se after utilizing the best treatment observed under the above greenhouse conditions.

EFFECTS OF SOIL SALINITY AND WATER STRESS ON SE VOLATILIZATION IN COTTON

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OBJECTIVES: To determine the Se-bioremediation potential of cotton grown under water and saline conditions similar to those found in agricultural soils on the westside of the San Joaquin Valley.

PROCEDURES: Seeds of *Gossypium hirsutum* var. GC-510 (cotton) were sown in 46 cm citrus liners containing 9 L of Panoche Clay loam soil [fine-loamy, mixed (calcareous), thermic Typic Torriorthents] from the U.C. Westside Field Station. All pots contained soil which was amended with 2.0 mg Se kg^{-1} soil as sodium selenite. The experiment was a split-split plot design with three replications. Main plots were two irrigation treatments; maintaining 30% field capacity and 50% field capacity, sub-plots were two soil salinity treatments (EC); 1-3 dS m^{-1} and 5-10 dS m^{-1}, and sub-sub plots were collection times for volatile Se; at 6 node stage and 12th node stage. Pots were weighed daily to estimate evapotranspiration losses. Water was added accordingly to maintain the respective irrigation treatment for each pot.

Additional soil pots (without plants) were added to each block which had microbial populations reduced through the application of the soil fumigant "Vapam". The presence of microbial populations was verified in Vapam and non-Vapam pots through the use of 'soil dilution series test'. Selenium volatilization was measured in Vapam soil pots and in non-Vapam soil pots; this estimated the contribution of soil microbial populations to total Se volatilization. Volatile Se was collected using Se volatilization collection chambers housed within an environmental growth chamber. Conditions within the growth chamber were maintained at a constant 30°C with a photo period of 16 h light (photon flux density of 850 μmol $m^{-2}s^{-1}$) and 8 h dark. Volatile Se collection chambers were constructed of transparent acrylic and measured 30 cm x 30 cm x 60 cm. Each chamber was equipped with a circulation fan and exhaust port filled with twelve pieces of activated charcoal filter each measuring 7.5 cm x 5 cm x 0.5 cm. The fan directed the air within the chamber through the charcoal trap and out the exhaust port; capturing volatile Se compounds in the activated charcoal filter. Filters were removed for analysis after four days. Volatilized Se was extracted from the charcoal filters by HNO_3/H_2O_2 digestion and analyzed by atomic absorption with continuous hydride generation.

RESULTS: Analysis of variance indicates that there were significant treatment effects on plant vegetative growth (Table 1) and that there was a significant difference between soil microbial populations of Vapam and non-Vapam soil control pots (Table 2). Despite significant treatment effects on vegetative growth and soil microbial populations, there was no significant treatment effect on rates of Se volatilization in cotton. Lack of treatment effects on Se volatilization rates may indicate that the system used to trap volatilized Se was not sensitive enough to use when Se volatilization rates are low (Table 3). Plant tissue Se concentrations were lower than those observed in other reported studies where selenate was the predominant form of Se in the soil (Table 4). There was no observed correlation between plant tissue Se concentrations and Se volatilization rates. Total plant tissue Se content was significantly influenced by irrigation treatment and soil analysis for total Se indicated that cotton did reduce the Se concentration in soil pots.

FUTURE PLANS: Cotton may reduce Se concentrations in Se-laden soils primarily through plant accumulation of Se and to a lesser extent by volatilization of Se. Field experiments may be important in determining the bioremediation advantages of rotating from cotton crops into true Se accumulating/volatilizing crop species such as broccoli, canola and mustard.

Table 1. Effect of treatments on vegetative growth parameters at time of collection of volatile Se.

Treatment‡	Actual % F.C.	Soil Salinity (dS m)	No. of Nodes	No. of Leaves	Leaf Surface Area (cm2/pot)	Avg. Plant Height (cm)	Root D.W. (g)	Shoot D.W. (g)
W1–S1–C1	31	4	8	35	845	24	3.15	9.78
W1–S1–C2	32	4	9	50	1394	34	5.41	23.22
W1–S2–C1	35	10	6	30	643	23	3.28	9.07
W1–S2–C2	31	11	9	35	875	27	4.46	13.63
W2–S1–C1	62	5	11	55	2788	48	8.41	35.15
W2–S1–C2	51	4	11	60	2957	47	10.19	41.15
W2–S2–C1	68	10	11	55	2493	42	7.95	34.17
W2–S2–C2	56	11	12	54	2769	49	7.91	36.82
LSD(0.05)†			1.69	16	415	9.24	2.65	9.05

†Represents the least significant difference between treatment means at the 0.05 level of confidence.
‡W = Irrigation Rate
W1 = Approx. 30% F.C.
W2 = Approx. 50% F.C.
S = Soil Salinity
S1 = Approx 1–3 dS m Soil Salinity
S2 = Approx 5–10 dS m Soil Salinity
C = Volatile Se Collection Time
C1 = Early Collection of Vol. Se (Approx. 6 node stage)
C2 = Late Collection of Vol. Se (Approx. 12 node stage)

Table 2. Microbial populations of Vapam and Non–Vapam "control Pots". †

Treatment‡	Dilution series #1 (millions)	Dilution series #2 (millions)	Dilution series #3 (millions)
W1–S1	2.8	4.3	53
W1–S2	2.4	3.5	52
W2–S1	2.2	4.4	42
W2–S2	2.4	4.1	44
W1–S1–V	1.4	1.6	42
W2–S1–V	1.3	1.9	46
LSD(0.05)†	0.31	0.52	n/s

†Represents the least significant difference between treatments at the 0.05 level of confidence.
‡W = Irrigation Rate
W1 = Approx. 30–35% F.C.
W2 = Approx. 50–69% F.C.
S = Soil Salinity
S1 = Approx 1–4 dS m Soil Salinity
S2 = Approx 5–10 dS m Soil Salinity
V = Vapam 'control pot'
n/s = No significant difference between treatment means at the 0.05 level of confidence.

Table 3. Effect of treatments on Se volatilization in cotton.†

Treatment‡	Volatile Se (µg/kg filter)	Volatile Se (µg Se/pot/day)	Volatile Se (µg Se/m2 LSA/day)§	Volatile Se (µg Se/kg plant dry wt./day)
W1–S1–C1	562	4	44	286
W1–S1–C2	607	4	28	135
W1–S2–C1	710	4	66	341
W1–S2–C2	599	4	49	236
W2–S1–C1	589	4	13	83
W2–S1–C2	548	3	11	65
W2–S2–C1	795	5	12	70
W2–S2–C2	566	3	12	75
W1–S1–C1–K	410	5	N/A	N/A
W1–S1–C2–K	456	4	N/A	N/A
W1–S2–C1–K	500	4	N/A	N/A
W1–S2–C2–K	472	4	N/A	N/A
W2–S1–C1–K	594	5	N/A	N/A
W2–S1–C2–K	595	4	N/A	N/A
W2–S2–C1–K	472	3	N/A	N/A
W2–S2–C2–K	568	5	N/A	N/A
W1–S1–V	528	4	N/A	N/A
W2–S2–V	591	4	N/A	N/A
LSD(0.05)§	N/A	N/A	19.2	107.5

†Represents the least significant difference between treatment means at the 0.05 level of confidence.

‡W = Irrigation Rate
W1 = Approx. 30–35% F.C.
W2 = Approx. 50–69% F.C.
S = Soil Salinity
S1 = Approx 1–4 dS m Soil Salinity
S2 = Approx 5–10 dS m Soil Salinity
C = Volatile Se Collection Time
C1 = Early Collection of Vol. Se (Approx. 6 node stage)
C2 = Late Collection of Vol. Se (Approx. 12 node stage)
K = Non–Vapam control
V = Vapam control

§LSA = Leaf Surface Area

N/A = no significant difference between treatment means at the 0.05 level of confidence.

Table 4. Effect of treatments on tissue Se concentrations at time of collection of volatile Se.

Treatment‡	%F.C.	Soil Salinity (dS m)	No. of Nodes	Shoot Se (mg Se/kg shoot dw)	Total Shoot Se (mg)	Root Se (mg Se/kg root dw)	Total Root Se (mg)
W1–S1–C1	31	4	8	7.3	0.10	15.2	0.06
W1–S1–C2	32	4	9	9.1	0.20	16.6	0.09
W1–S2–C1	35	10	6	8.4	0.21	15.4	0.05
W1–S2–C2	31	11	9	7.5	0.08	13.7	0.05
W2–S1–C1	62	5	11	6.7	0.22	8.5	0.08
W2–S1–C2	51	4	11	6.4	0.24	11.0	0.07
W2–S2–C1	68	10	11	6.3	0.20	10.0	0.12
W2–S2–C2	56	11	12	5.4	0.27	8.7	0.11
LSD(0.05)†			1.69	N/A	0.107	N/A	0.047

†Represents the least significant difference between treatment means at the 0.05 level of confidence.

‡W = Irrigation Rate
W1 = Approx. 30% F.C.
W2 = Approx. 50% F.C.
S = Soil Salinity
S1 = Approx 1–3 dS m Soil Salinity
S2 = Approx 5–10 dS m Soil Salinity
C = Volatile Se Collection Time
C1 = Early Collection of Vol. Se (Approx. 6 node stage)
C2 = Late Collection of Vol. Se (Approx. 12 node stage)

USING TALL FESCUE TO REMEDIATE BORON-LADEN SOILS

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P. Treffy, and D. Hershelbach

OBJECTIVES: Evaluate the ability of tall fescue to simultaneously tolerate and remove extractable soil B.

PROCEDURES: A multiple year field study was conducted on native B-laden soils (>5 mg extractable B L^{-1}) on Three Way Farms near Los Banos, California. The treatment design was a complete randomized block with each treatment replicated six times. Treatments consist of "cropped plots" and "bare plots" (controls; no plants). Each cropped plot (17m x 17m) was drill planted to *Festuca arundincea* (tall fescue) to a depth of 10 mm at a rate of 10 kg ha^{-1}. Two access tubes were installed in each plot to a depth of 2 m. All plots were managed and sprinkle-irrigated with California aqueduct water (EC <0.8 dSm^{-1}) based on weather data acquired through the CIMIS system in Los Banos and readings taken every 10 d with the neutron probe. Four soil samples were collected from each of two depths (0-45 and 45-90 cm) within each respective plot from May 1 to October 15 in 1992 and 1993. Preplant soil concentrations of selected parameters are shown in Table 1.

Plants were mechanically swathed to a height of 20 cm every 60 d during the growing season for a total of three clippings each year. Prior to each swathing, subsamples of tall fescue were hand clipped from four, one meter squared sampling sites within each plot. Samples were washed, oven-dried at 50°C, weighed, and ground in a Wiley mill.

Plant tissue was wet acid digested with nitric acid/hydrogen peroxide/HCl and water soluble soil B was extracted from a saturated paste. All B samples were analyzed using an Emission Spectrometer Inductively Coupled Plasma (Perkin Elmer Plasma 2000).

RESULTS: Concentrations of B measured in the harvested plant material seldom exceeded 130 mg B kg^{-1} DM (Table 2). Yields increased with each subsequent clipping and with the subsequent year (Table 2). Preliminary data from the first two years indicate that tall fescue can both be successfully grown on high-B soils and positively contribute to the long-term management of reducing soil B levels (Table 3).

FUTURE PLANS: Although tall fescue planted for environmental reclamation is not the long-term solution to removing high levels of soil B, the planting of tall fescue in conjunction with more efficient irrigation practices and drainage water management may ameliorate the negative effects that high soil B exerts on plants. Future studies will evaluate the long term effects of growing tall fescue for multiple years on the lowering of soil B levels. Moreover, animal forage studies will be conducted with harvested tall fescue used for B remediation. A manuscript is being prepared.

Table 1. Mean acid soluble soil concentrations of selected trace elements at preplant in 1992, 1993 and 1994 in the soil profile (0–90 cm) of all plots†.

Year	Total Concentrations of Selected Elements:								Other Parameters	
	Zn	Cd	Mn	Cu	Mo	Se	Fe	Al	pH	EC
	(mg kg^{-1} soil)						(%)		(dSm^{-1})	
1992	50(2.1)	8.1(0.6)	600(65)	20(5.1)	1.0(0.1)	0.7(0.1)	1.1(0.2)	3.9(0.4)	7.8(0.3)	2.8(0.1)
1993	47(2.2)	6.4(0.9)	727(71)	24(4.8)	0.8(0.1)	0.5(0.1)	1.0(0.4)	4.2(0.3)	7.7(0.3)	3.2(0.1)
1994	41(2.4)	5.2(1.0)	575(61)	18(3.9)	0.6(0.2)	0.4(6.1)	0.9(0.3)	3.8(0.2)	7.8(0.2)	3.9(0.3)

†Values are the mean concentrations from a minimum of 100 samples taken each year followed by the standard error in parenthesis.

Table 2. Dry matter (DM) yield and tissue B concentrations in clippings from tall fescue during 1992, 1993 and 1994 growing period†.

Year	Clipping	DM yield	Boron Concentrations in: Shoot	Root
		($g\ m^{-2}$)	($mg\ kg^{-1}$ DM)	
1992				
	1	262	88	NA
	2	776	105	NA
	3	872	110	57
1993				
	1	1211	118	NA
	2	1391	121	NA
	3	1494	121	61
1994				
	1	1522	131	NA
	2	1491	124	NA
	3	1510	123	65
S.E.‡		.31	3.0	2.6

†Values are the mean yield from a minimum of 24 individual square meter sampling sections.
‡Standard error.
NA Not applicable.

Table 3. Changes in soil B concentrations throughout the growing seasons in plots planted (cropped) and not planted (control) to tall fescue in 1992–94†.

Treatment in plots	Time of sampling	Soil Depth (cm)	Soil B concentrations: Extractable B ($mg\ B\ L^{-1}$)	Total B ($mg\ B\ kg^{-1}$ soil)
1992				
Control	Preplant	0–45	5.0(0.4)	37.6(3.3)
Control	Postharvest	0–45	4.3(0.4)	36.5(3.1)
Cropped	Preplant	0–45	5.9(0.5)	37.6(3.3)
Cropped	Postharvest	0–45	4.3(0.4)	35.2(3.3)
1992				
Control	Preplant	45–90	6.1(0.5)	38.5(1.7)
Control	Postharvest	45–90	6.0(0.4)	37.3(1.8)
Cropped	Preplant	45–90	5.3(0.4)	42.6(2.5)
Cropped	Postharvest	45–90	4.3(0.3)	40.4(2.3)
1993				
Control	Preplant	0–45	4.2(1.6)	37.6(3.3)
Control	Postharvest	0–45	4.0(0.4)	35.2(3.3)
Cropped	Preplant	0–45	4.1(0.4)	41.4(2.4)
Cropped	Postharvest	0–45	3.5(0.4)	39.3(2.0)
1993				
Control	Preplant	45–90	6.1(0.4)	39.6(2.6)
Control	Postharvest	45–90	6.2(0.4)	38.2(2.7)
Cropped	Preplant	45–90	4.2(0.4)	41.4(2.4)
Cropped	Postharvest	45–90	3.7(0.4)	39.3(2.0)
1994				
Control	Preplant	0–45	3.7(1.3)	36.5(2.8)
Control	Postharvest	0–45	3.5(0.2)	34.1(2.9)
Cropped	Preplant	0–45	4.1(0.6)	37.2(3.1)
Cropped	Postharvest	0–45	3.2(0.7)	34.6(2.6)
1994				
Control	Preplant	45–90	4.0(0.5)	40.2(2.6)
Control	Postharvest	45–90	4.2(0.6)	39.8(3.1)
Cropped	Preplant	45–90	3.5(0.5)	38.1(1.6)
Cropped	Postharvest	45–90	3.0(0.3)	36.0(2.1)

†Values presented represent the mean concentrations from all six plots (48 samples) for each treatment, respectively, followed by the standard error in parenthesis.

SURVEY OF INSECTS ATTRACTED TO DIFFERENT PLANT SPECIES USED FOR BIOREMEDIATION OF BORON-LADEN SOILS

G.S. Bañuelos, S. Tebbets, F. Cardenas,
M. Hannel, S. Zambrzuski, and P. Vail

OBJECTIVES: Identify the insects which are inhabiting the following plants used for bioremediation of B-laden soils: Indian mustard, kenaf, birdsfoot trefoil, and tall fescue.

PROCEDURE: A three year study is being conducted to collect insects inhabiting different plant species grown to bioremediate boron-laden soils on Three Way Farms, Los Banos, California. The treatment design was a complete randomized design with each treatment replicated three times. Treatments consisted of the following plant species growing on adjacent 20 m^2 plots: *Brassica juncea* (Indian mustard), *Festuca arundincea* (tall fescue), *Lotus corniculatus* (birdsfoot trefoil), and *Hibiscus cannabinus* (kenaf). All plots were managed and sprinkle irrigated identically on the B-laden soil. Forty-five days after emergence, each plot was sampled weekly at 10 A.M. for insects using an insect sweep net. There were a total of 15 sampling dates throughout the designated growing season. Each sample consisted of eight sweeps progressing from the outside of the plot towards the middle. Collected insects were placed in a glass jar, frozen, stored in alcohol, and identified later.

RESULTS: Due to the large number of insects attracted to the flowering species (birdsfoot trefoil, kenaf, and Indian mustard), in-depth identification of these species will require more time. Consequently the initial screening consisted of separating the insects into a general insect classification (Table 1) and separating into "beneficials" and "predators".

FUTURE PLANS: The in-depth identification of insects is actively being pursued. Insect sampling will continue to take place for the second year. A future study will include planting only those plant species for soil B remediation which attract the fewer potentially harmful insects.

Table 1. General survey of the predominate insects habitating different crop species used for the bioremediation of boron-laden soils.*

Crop Species:	Insects: Family:	Genus sp. or Common name:
Birdsfoot trefoil	Miridae	*Lygus sp.*
	Thripidae	*Frankliniella sp.* (Western flower thrips)
	Cicadellidae	*Empoasca sp.* (Leafhopper)
		Aceratagallia sp.
		Colladonus mountanus
Indian mustard	Miridae	*Lygus sp.*
	Thripidea	*Frankliniella sp.* (Western flower thrips)
	Chrysomelidae	Subfamily: Alticinae (Flea Beetle)
	Rhopalidae	*Liorhyssus hyalinus* (Hyaline grass bug)
		Adults and nymphs were found.
	Pentatomidae	Stink bugs
	Cicadellidae	*Empoasca sp.* (Leafhoppers)
Tall fescue	Thripidae	*Frankliniella sp.* (Western flower thrips)
	Aeolothripidae	Banded thrips
	Chrysomelidae	Subfamily: Alticinae (Flea Beetles)
	Rhopalidae	*Liorhyssus hyalinus* (Hyaline grass bug)
	Cicadellidae	*Amblysellus grex* (Hopper)
		Euscelis obsoletus
		other
	Delphacidae	Plant hoppers
	Coccincellidae	Ladybird beetles and other
Kenaf	Miridae	*Lygus sp.*
	Cocincellidae	*Hypersapis sp.*
	Cicadellidae	*Empoasca sp.* (Leafhopprs)
		Aceratagallia sp.
	Lepidoptera	Salt Marsh caterpillar
Cotton	Miridae	*Lygus sp.*
	Cicadellidae	*Empoasca sp.* (Leafhopper)
	Chrysomelidae	Subfamily: Alticinae (Flea Beetle)
Fallow (weeds)	Thripidae	*Frankliniella sp.* (Western flower thrips)
	Lygaeidae	*Nysius raphanus* (False chinch bug)

*Insects are not ranked in order of predominance. Predominance varies with time of year.

WATER REQUIREMENTS OF SUBSURFACE DRIP IRRIGATED CANOLA IN THE SAN JOAQUIN VALLEY: I. OPERATIONAL PROCEDURES AND YIELD RESPONSE

G.S. Bañuelos, R. Hutmacher, and S. Downey

OBJECTIVES: To evaluate the water requirement of canola (*Brassica napus*) irrigated with subsurface drip irrigation (SDI) in the east side of the San Joaquin Valley, and to evaluate plant growth response to different irrigation treatments in order to determine optimum irrigation rates for biomass production.

PROCEDURES: Drip lines (Geo-flow) were installed in a Hanford sandy loam soil in the center of each planting bed at a depth of 39 cm. Emitters on the drop laterals were spaced 1.02 m apart and were of a turbulent-flow design with a nominal output of 2 L h^{-1}. Each plot consisted of five beds, 1.52 m wide and 12 m in length. There were five irrigation treatments with four replications each arranged in a randomized complete block design. Treatments were designed to receive 50%, 75%, 100%, 125% and 150% of calculated ETc, respectively, but actually received 47%, 64%, 100%, 122% and 143% of estimated ETc. Irrigation treatments were monitored with water meters and were controlled by a Hardie controller. Applications of N, P, and K were made with the Dosatron fertilizer injector through the SDI as calcium ammonium nitrate and phosphoric acid. A total of 74 kg N ha^{-1} and 224 kg P ha^{-1} were added (including both pre-plant and within-season applications made with the irrigation). Twenty neutron probe access tubes were installed (one per plot).

In February 1994, pre-plant herbicide (Treflan) was applied to soils within the treatments at the rate of 1.95 l ha^{-1} and pre-plant fertilizer (16-16-16) was applied at a rate of 163 kg N ha^{-1} uniformly across all treatments. Herbicide and fertilizer were then incorporated to a depth of 15 cm in all treatments. In March 1994, two rows of canola (*Brassica napus* var. Westar) were planted per 1.52 m east-west oriented bed. During the period from planting to harvest, 25.5 mm of rain fell. Seed was germinated using 97 mm of sprinkler irrigation. Irrigation was controlled to meet some multiple of crop evapotranspiration (ETc), as determined using CIMIS reference evapotranspiration data from University of California Kearney Research Center and multiplied by a crop coefficient determined by percent cover of the canola crop canopy. All plant samples were taken on 2 m sections of two beds in each plot. Leaf surface area and root dry weight were taken several times during the growing season to assess relative effects of treatments on plant growth and development. Samples were taken to determine leaf surface area 43, 58 and 70 days after planting (DAP). Samples for root dry weight were taken 58 and 70 DAP. Final plant harvest and determination of total harvest dry weight, leaf dry weight and stem dry weight took place 70 DAP.

RESULTS: Preliminary data of total harvest dry weight treatment means were significantly different ($P<0.10$) and there was a significant linear increase of total harvest dry weight with increased water application ($P<0.010$). Leaf surface area showed no treatment effects at 43 DAP but exhibited treatment effects by 58 and 70 DAP. Leaf surface area showed significant treatment effects ($P<0.095$) and significant linear increase with increased water application ($P<0.010$) on both sampling dates (Table 1). All other plant growth

Table 1. Effects of different irrigation treatments on biomass yield and leaf surface area of individual canola plants.†

Treatment	Harvest dry weight (plant^{-1})	Leaf surface area 58 DAP‡ (cm^2)	Leaf surface area 70 DAP (cm^2)
1	29	125	85
2	31	145	94
3	37	173	113
4	35	169	133
5	38	188	130

†Values presented are means from four replications each consisting of ten plants, respectively.
‡DAP Days after planting.

parameters (e.g. root dry weight, leaf dry weight and stem dry weight) showed no significant differences nor significant linear trends on any sampling date.

FUTURE PLANS: Since it is possible to grow two crops of canola each year in the San Joaquin Valley, further water requirement experiments with canola on SDI will be performed in a effort to more precisely define the irrigation rates required for optimum biomass production.

WATER REQUIREMENTS OF SUBSURFACE DRIP IRRIGATED CANOLA IN THE SAN JOAQUIN VALLEY: II. SOIL MOISTURE CONTENT MEASUREMENTS

G.S. Bañuelos, R. Hutmacher, and S. Downey

OBJECTIVES: To evaluate the water requirement of canola (*Brassica napus*) irrigated with subsurface drip irrigation (SDI) in the eastside of the San Joaquin Valley, and to evaluate plant growth response to different irrigation treatments in order to determine optimum irrigation rates for biomass production.

PROCEDURES: For a general description of the plot layout and basic operational procedures, see "*Water Requirements of Subsurface Drip Irrigated Canola in the San Joaquin Valley: Operational Procedures and Yield Response*" in this volume. There are five irrigation treatments with four replications in a randomized complete block design. Treatments #1, 2, 3, 4, and 5 were designed to receive 50%, 75%, 100%, 125% and 150% of calculated ETc, respectively, but actually received 47%, 64%, 100%, 122% and 143% of estimated ETc. Irrigation rates were determined by using crop evapotranspiration (ETc), as determined using CIMIS reference evapotranspiration data from University of California Kearney Research Center multiplied by a crop coefficient determined by percent cover of the canola crop canopy. Twenty neutron probe access tubes were installed with one access tube per plot, positioned midway between emitters and approximately 15 cm laterally from the drip line. Soil moisture content was monitored with bi-weekly sampling using a neutron probe at 15 cm depth increments to an average depth of 225 cm.

RESULTS: Gravimetric soil samples indicated that low soil water content developed in the upper 15 to 30 cm of the beds under the planted rows after sprinkling was discontinued. Stored soil water data was collected by neutron probe from treatments #1, 3 and 5 only. Net soil water depletion was determined for these treatments at soil depths below 30 cm and the estimated crop evapotranspiration (ETc) was calculated for three periods during the growing season. Those periods were 8 days before planting to 29 days after planting; 29 days to 50 days after planting; and 50 days to 70 days after planting. Soil water extraction and/or upward movement of soil water due to a drying soil profile and soil water extraction by roots occurred in every treatment over the duration of the experiment down to a depth of approximately 122 cm. Below this depth, however, there was a trend toward net increases in stored soil water in treatment 5. Based on a comparison of potential ETr, calculated ETc and soil water depletion for treatments #1, 3 and 5, net increases in soil water content occurred when total applied water approached treatment 5 levels (150% ETc). This indicates that peak ETc for canola grown for 70 days during this part of the year would be between 231 and 246 mm.

FUTURE PLANS: Canola will be grown during both spring and fall seasons in the future in an effort to more accurately determine the water requirements of this crop for use in bioremediation in the San Joaquin Valley.

WATER REQUIREMENTS OF SUBSURFACE DRIP IRRIGATED KENAF VARIETIES IN THE SAN JOAQUIN VALLEY: I. OPERATIONAL PROCEDURES AND YIELD RESPONSE

G.S. Bañuelos, R. Hutmacher, S. Downey, and C. Cook

OBJECTIVES: To evaluate the water requirement of kenaf varieties (*Hibiscus cannabinus* var.) irrigated with subsurface drip irrigation (SDI) in the San Joaquin Valley, and to evaluate variety growth response to different irrigation treatments in order to determine optimum irrigation rates for kenaf production.

PROCEDURES: Drip lines (Geo-flow) were installed in a Hanford sandy loam soil in the center of each planting bed at approximately a depth of 38 cm. Emitters on the drip laterals were spaced 1.02 m apart and were of a turbulent-flow design with a nominal output of 2 L h^{-1}. Each plot consisted of five beds, 1.52 m wide and 12 m in length. There were five irrigation treatments with four replications each arranged in a randomized complete block design. Treatments #1, 2, 3, 4 and 5 were designed to receive 25%, 50%, 100%, 125%, and 150% of calculated ETc, respectively, but actually received 27%, 50%, 100%, 125% and 157% of estimated ETc. Irrigation treatments were monitored with water meters and were controlled by a Hardie controller. N, P and K fertilizers were supplied to each treatment by the use of a Dosatron fertilizer injector. A total of 135 kg N ha^{-1} and 41 kg P ha^{-1} were added (including both pre-plant and within-season applications made with the irrigation). N and P applications made with the SDI were as calcium ammonium nitrate and phosphoric acid, respectively. Twenty access tubes were installed (one per plot).

In May 1994, pre-plant herbicide (Treflan) was applied to all treatments at the rate of 1.95 L ha^{-1} and pre-plant fertlizer (15-15-15-10) was applied at a rate of 217 kg N ha^{-1} uniformly across all treatments. Herbicide and fertilizer were then incorporated to a depth of 15 cm in all treatments.

In June 1994, six varieties of kenaf (7-N, C-531, C-533, EV-41, TA-2, and Indian) were planted in a split plot design. Main plots were irrigation treatments and sub-plots were kenaf varieties. Two rows of kenaf were planted on each of five beds per plot. Rows were approximately 30 cm apart and each 12 m length of bed was planted with 6 m of Indian kenaf and 6 m of one other variety. During the period from planting to harvest, 14 mm of rain fell. Seed was established using 25 mm of sprinkler irrigation. Irrigation was controlled to meet the estimated crop evapotranspiration (ETc) as determined using CIMIS reference evapotranspiration data from University of California Kearney Research Center and multiplied by a crop coefficient determined by percent cover of the kenaf crop canopy.

All plant samples were taken on 2 m sections of each variety in each plot. Samples were taken to determine shoot dry weight, root dry weight, leaf dry weight, stem dry weight, and bast:core ratio.

RESULTS: Preliminary data show there were significant treatment effects on root and shoot dry weights as well as leaf and stem dry weights and leaf:stem ratio (Fig. 1-7). Root:shoot ratio and bast:core ratio, however, remained constant over all treatment levels. There was some variety effect on root dry weight.

FUTURE PLANS: Further water requirement experiments with kenaf on SDI will be performed in an effort to more precisely define the irrigation rates required for optimum kenaf production during the summer in the San Joaquin Valley.

Fig. 1. Shoot dry weight in kenaf varieties (Mg/ha)*

Trt % ETc	7-N	C-531	C-533	EV-41	TA-2	INDIAN
25	15.0	17.8	9.2	10.4	14.2	18.1
50	22.3	18.1	11.5	19.5	17.9	27.0
100	34.2	44.9	19.1	38.0	44.0	38.2
125	36.5	35.2	21.6	32.4	32.2	38.6
150	40.8	39.2	31.5	42.8	30.0	38.2

Fig. 2. Leaf dry weight in kenaf varieties (Mg/ha)*

Trt % ETc	7-N	C-531	C-533	EV-41	TA-2	INDIAN
25	5.7	7.1	4.4	4.9	7.8	6.7
50	7.1	7.7	4.3	8.1	7.3	7.6
100	9.8	10.6	9.9	10.9	11.1	9.1
125	12.3	12.4	10.9	10.2	10.7	9.7
150	10.7	9.4	13.8	12.9	19.2	14.4

Fig. 3. Stem dry weight in kenaf varieties (Mg/ha)*

Trt % ETc	7-N	C-531	C-533	EV-41	TA-2	INDIAN
25	14.1	18.9	14.3	16.7	25.7	24.8
50	14.6	14.5	15.9	12.8	14.0	22.8
100	40.3	24.2	19.1	22.5	32.2	33.5
125	35.9	42.3	31.2	34.4	36.5	27.1
150	21.5	18.6	23.6	23.7	38.1	26.3

Fig. 4. Root dry weight in kenaf varieties (Mg/ha)*

Trt % ETc	7-N	C-531	C-533	EV-41	TA-2	INDIAN
25	6.0	3.7	3.6	3.6	5.6	2.9
50	4.0	4.4	2.4	3.7	3.7	4.3
100	7.4	4.8	2.1	6.8	6.7	4.8
125	4.8	2.7	4.2	6.9	6.5	3.8
150	5.2	5.8	3.1	6.6	8.5	5.8

Fig. 5. Leaf:stem ratio in kenaf varieties

Trt % ETc	7-N	C-531	C-533	EV-41	TA-2	INDIAN
25	0.41	0.37	0.32	0.29	0.30	0.26
50	0.48	0.54	0.46	0.64	0.53	0.36
100	0.24	0.44	0.52	0.48	0.51	0.26
125	0.35	0.29	0.36	0.30	0.28	0.29
150	0.50	0.51	0.59	0.54	0.51	0.55

Fig. 6. Root:shoot ratio in kenaf varieties

Trt % ETc	7-N	C-531	C-533	EV-41	TA-2	INDIAN
25	0.40	0.21	0.40	0.35	0.39	0.16
50	0.18	0.24	0.21	0.19	0.21	0.16
100	0.12	0.11	0.11	0.18	0.15	0.13
125	0.13	0.13	0.16	0.34	0.20	0.10
150	0.13	0.15	0.10	0.15	0.28	0.15

Fig. 7. Bast:core ratio in kenaf varieties

Trt % ETc	7-N	C-531	C-533	EV-41	TA-2	INDIAN
25	0.44	0.32	0.29	0.49	0.41	0.34
50	0.34	0.29	0.30	0.41	0.39	0.30
100	0.35	0.25	0.31	0.41	0.37	0.32
125	0.47	0.42	0.30	0.43	0.35	0.38
150	0.47	0.38	0.36	0.45	0.33	0.42

*Based on 247,000 plants/ha.

Highlighted numbers are the highest values for the respective cultivars.

Figures 1–7. Different parameters measured in various cultivars of kenaf irrigated with assorted water treatments.

WATER REQUIREMENTS OF SUBSURFACE DRIP IRRIGATED KENAF VARIETIES IN THE SAN JOAQUIN VALLEY: II. SOIL MOISTURE CONTENT MEASUREMENTS

G.S. Bañuelos, R. Hutmacher, S. Downey, and C. Cook

OBJECTIVES: To evaluate the water requirement of kenaf varieties (*Hibiscus cannabinus* var.) irrigated with subsurface drip irrigation (SDI) in the San Joaquin Valley, and to evaluate plant growth response to different irrigation treatments in order to determine optimum irrigation rates for kenaf production.

PROCEDURES: For a general description of the plot layout and basic operational procedures, see "*Water Requirement of Subsurface Drip Irrigated Kenaf Varieties in the San Joaquin Valley: I. Operational Procedures and Yield Response*" in this volume. There are five irrigation treatments and six kenaf varieties with four replications in a split plot design. Soil water content was estimated on main plots only. No effort was made to collect soil water content and crop evapotranspiration data on individual varieties.

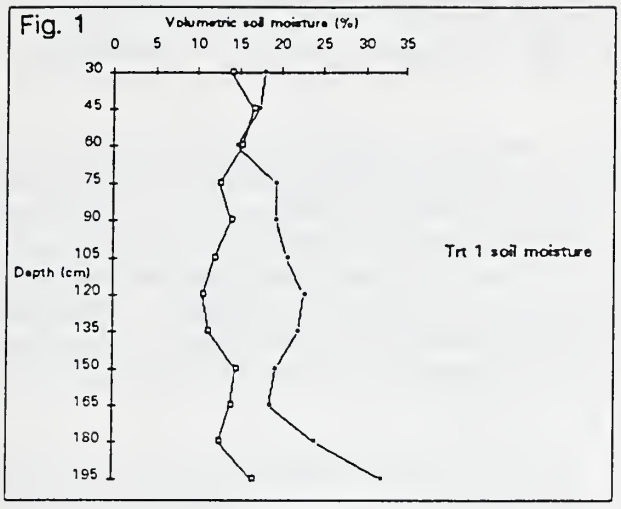
Irrigation was controlled to meet crop evapotranspiration (ETc), as determined using CIMIS reference evapotranspiration data from University of California Kearney Research Center and multiplied by a crop coefficient determined by percent cover of the kenaf crop canopy. Treatments #1, 2, 3, 4 and 5 were designed to receive 25%, 50%, 100%, 125% and 150% of calculated ETc, respectively, but actually received 27%, 50%, 100%, 125% and 157% of estimated ETc (Table 1). Twenty access tubes were installed with one access tube per main plot, positioned midway between emitters and approximately 15 cm laterally from the drip line. Soil moisture content was monitored with bi-weekly sampling using a neutron probe at 15 cm increments to an average depth of 225 cm.

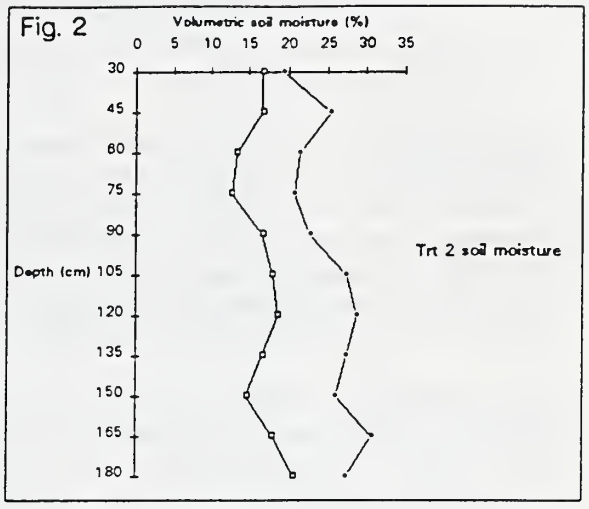
RESULTS: Preliminary data collected from gravimetric soil samples indicate that low soil water content developed in the upper 15 to 30 cm of the beds under the plant rows after sprinkling was discontinued (data not presented). Volumetric soil moisture is shown in Figures 1-5 for different soil depths for different treatments. Net soil water depletion was determined for all treatments at soil depths below 30 cm and the estimated crop evapotranspiration (ETc) was calculated for three periods during the growing season. Those periods were: 1) 31 days to 58 days after planting; 2) 58 days to 92 days after planting; 3) and 92 days to 148 days after planting. Soil water extraction and/or upward movement of soil water due to a drying soil profile and soil water extraction by roots occurred in every treatment over the dura-tion of the experiment down to a depth of approximately 200 cm. Below this depth, however, there was a trend toward net increases in stored soil water in treatment 5. Based on a comparison of potential ETr, calculated ETc and soil water depletion for all treatments, net increases in soil water content occurred below 200 cm when total applied water approached treat-ment 5 levels (150% ETc). This indicates that peak ETc for kenaf grown for 148 days during the summer would be between 500 and 600 mm.

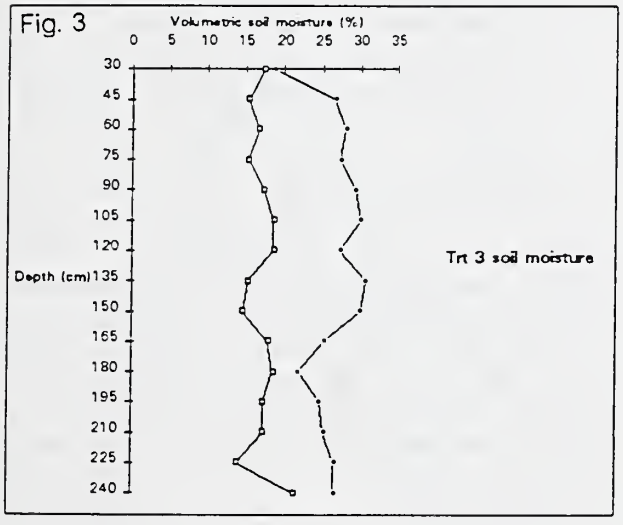
Table 1. Selected parameters used for approximating water application rate.

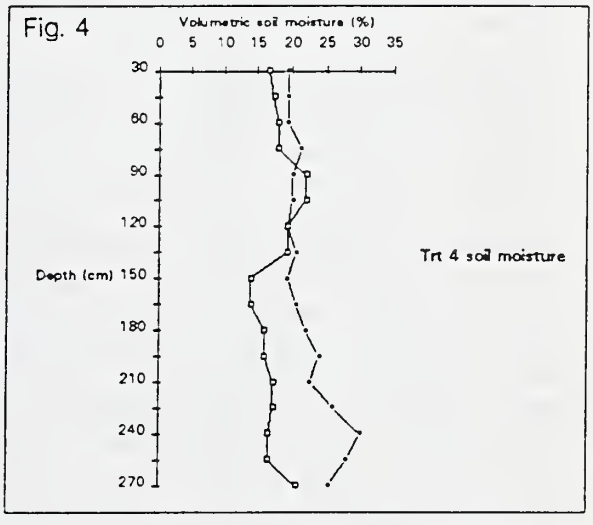
Treat-ment	(a) Total applied water (mm)	(b) Precipi-tation (mm)	(c) Net soil water depletion (mm)	(d) Est. soil perco-lation (mm)	(e) Calculation crop ETc (ETc=a+b+c+d) (mm)	(f) Potential ETr (mm)	Et_c/Et_r
1	95	0	125	0	220	418	0.23
2	190	0	141	0	331	418	0.45
3	379	0	175	0	554	418	0.91
4	473	0	49	0	522	418	1.13
5	593	0	78	0	671	418	1.42

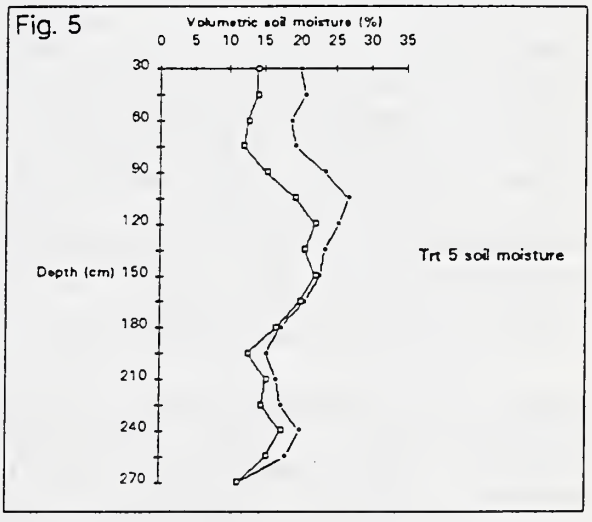
FUTURE PLANS: Kenaf will be grown during the summer in the future in an effort to more accurately determine the water requirements of this crop for use in bioremediation in the San Joaquin Valley.

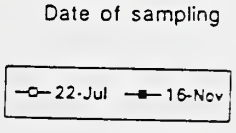












Figures 1–5. Volumetric soil moisture percentages at different soil depths for different water treatments.

EVALUATING KENAF STRAINS FOR ADVERSE CONDITIONS

C.G. Cook, A.W. Scott, Jr., J.W. Sij, M.S. Bhangoo, and G.S. Bañuelos

OBJECTIVE: In order to improve kenaf yields through breeding and cultural practices one must first identify the limiting constraints to production, followed by the evaluation of germplasm and cultural management strategies with which to overcome these adversities.

PROCEDURE: From 1990-1994, various kenaf cultivars were evaluated for total stalk yield at several potential kenaf production areas, which include Weslaco, Beaumont, and Overton, Texas; Fresno, California; Lane, Oklahoma; Bossier City and Crowley, Louisiana; and Grenada and Iha Bena, Mississippi. Plot length and row width differed between locations (varied between 60-90 cm); however, plots consisted of four rows. Statistical design was a randomized complete block with four replications. At each location, a center row section of 4 m was harvested from each plot and plants were weighed. Moisture percent was determined from a 6-plant sample from each plot in two replications. After oven-drying, the percent dry weight was calculated and used to convert plot yields to a dry weight basis. Identical harvesting procedures and statistical design were used for the advanced strains testing at Weslaco and Beaumont and in the nematode infested plots at Weslaco. Single row plots were used in these tests, with the Weslaco and Beaumont strains test having four and two replications in 1993 and six and four replications in 1994. At the Weslaco root-knot nematode nursery, six replications were used in both years.

RESULTS: Preliminary results from the Uniform Kenaf Variety tests have indicated that cultivars 19-117-2 (PI 468076), SF45-9, Tainung 2, and Everglades 71 are the most consistent yielding cultivars, while 15-2 (PI 468075) consistently produces the lowest yields (data not presented). The 15-2 line was utilized to increase the populations of *M. incognita* (race 3) at the nursery in which cultivar SF459 was selected. In 1993-1994, the cordate-leaf experimental strain, 7N, produced greater yields than all other cordate-leaf cultivars in the Uniform Kenaf Variety test at Fresno, California. However, this line does not show consistent advantages in productivity at the other locations.

In 1993, 14 new strains were compared to Everglades 71, Everglades 41, Cuba 108, and Tainang 1 at the Weslaco location, which had a moderate population of root-knot nematodes. Eight of the 14 tested strains produced both greater bast and total stalk yields than the check cultivars. In the 1994 test, on nematode-free soils, 24 strains were compared with eight check cultivars. Nine of the experimental strains produced greater total stalk yields than Cubano, Everglades 71, Tainung 1, Cuba 108, and 7804, a widely grown cultivar in the Peoples Republic of China. At the Beaumont location, where biotic adversities are not generally present, three of the 10 evaluated strains produced greater yields than Cuba 108, but were not different from the other three checks, Tainung 1, Everglades 41, and Everglades 71. At Fresno, several strains, i.e. Tainung 1 and 2, showed excellent promise and will be evaluated on a larger scale in 1995.

A field study conducted in 1993 on soils infested with the RKN/SBF complex at Weslaco indicated that all 11 strains produced greater stalk yields than Everglades 71. The greatest stalk yield was produced by SF459, a strain that was released as a variety by the USDA-ARS and Rio Farms, Inc. in November 1994. In the 1994 test at the same location, three of the six experimental lines produced greater yields than Everglades 71, while cultivar SF459 produced the greatest yield in the presence of the RKN/SBF complex and was significantly better in yield than all tested entries. Incidence of plant death

in 1994 ranged from 24.2% for SF459 to 61.3% for Everglades 71. Four of the six lines had a lower incidence of plant death than Everglades 71.

Another new strain, designated PVWF-90, has shown an extremely high level of resistance to powdery mildew, a fungus that has been observed to attack the foliage of fall kenaf seed crops. The resistant characteristic is currently being transferred into higher yielding genetic backgrounds. Hybrids produced with this parent have shown excellent heterosis and powdery mildew resistance. Therefore the potential to develop good genetic material from the crosses remains high.

FUTURE PLANS: Continue the evaluation trials and continue processing the collected data. A manuscript will be prepared and submitted.

SEED INCREASE AND EVALUATION OF DIFFERENT PLANT SPECIES GROWN AT UNIVERSITY OF CALIFORNIA KEARNEY RESEARCH CENTER

R. Hannan, G.S. Bañuelos, S. Zambrzuski, J. Chevalier, and R. Clark

OBJECTIVE: The objective of this experiment is to:

1. Evaluate the Kearney/Parlier site for future use by the Western Regional Plant Introduction Station.
2. Increase seed of selected plant species from different Plant Introduction Stations.

PROCEDURE: During the spring and summer of 1994, various species of plants were grown at the University of California Kearney Agriculture Research Center in Parlier, California (see Fig. 1). Seeds provided by different Plant Introduction Stations throughout the USA were planted by the Planter Jr. to a depth of 2 cm in a Hanford sandy loam soil on raised beds set on 75 cm centers. The plots ran east to west, with eight accessions per row, except for the cucurbit row which had five plots. The planted rows were 2.3 m in length. Due to the extremely variable seed types, sizes, and shapes, a hoe was used to line out the row at what seemed an appropriate depth for the specific seed type. All seed was treated with Captan 50WP prior to planting. The field was sprinkler irrigated for several weeks after planting and then furrow irrigated for the remainder of the season. Approximately once a week, the site was evaluated for plant growth, weeds, insect infestation, fertilizer, and irrigation needs. After most varieties flowered and went to seed, seed was collected from all surviving plants and shipped to Rich Hannan.

RESULTS: Based upon plant survival and production of seed, the Kearney/Parlier site appears to be an ideal location for most of the tested species. Soil type, water availability, and climate (over 315 frost free days per year) were favorable characteristics for seed production.

FUTURE PLANS: Continue to evaluate the Kearney/Parlier site for future use by the Western Regional Plant Introduction Station. Seed was distributed to the appropriate curator and will be tested for seed viability. Plant a spring crop at the same site and collect seed for evaluation by the curators.

Figure 1. List of the different plant species evaluated in 1994 at University of California Kearney Agriculture Research Center.

Family	Genus	Species	Common name	Origin	Notes
Ameranthacea	Ameranthus	species	ameranth	India	collected seed
Apiaceae	Coriandrum	sativum	parsley	India	collected seed
Asteraceae	Aster	spathulifolius	aster	Korea	dead (no seed)
Asteraceae	Guizotia	abyssinica	niger	India	collected seed
Asteraceae	Helianthus	annuus	sunflower	Turkey	collected seed
Asteraceae	Lactuca	sativa	lettuce	Czechoslovakia	collected seed
Asteraceae	Veronia	anthelmintica	ironweed	Pakistan	collected seed
Asteraceae	Zinnia	haageana	zinnia	Germany	collected seed
Brassicaceae	Lesquerella	gordonii	bladderpod	United States	dead (no seed)
Brassicaceae	Raphanus	sativus	radish	Turkey	collected seed
Chenopodiaceae	Atriplex	semibaccata	saltbush	South Africa	collected seed
Cucurbitaceae	Citrullus	coloynthis	colocynth	Afghanistan	collected seed
Cucurbitaceae	Cucumis	metuliferis	melon	Zimbabwe	dead (no seed)
Cucurbitaceae	Cucumis	melo	melon	Senegal	collected seed
Cucurbitaceae	Cucurbita	pepo	squash	Mexico	collected seed
Cucurbitaceae	Cucurbita	maxima	melon	Argentina	collected seed
Fabaceae	Astragalus	cicer	milk vetch	Czechoslovakia	collected seed
Fabaceae	Crotalaria	saltiana	crotalaria	Thailand	dead (no seed)
Fabaceae	Dalea	leporina	dalea	United States	collected seed
Fabaceae	Hedysarum	coronarium	sweet vetch	Spain	collected seed
Fabaceae	Lathyrus	sativus	grass pea	Turkey	collected seed
Fabaceae	Lathyrus	japonicus	sea pea	Norway	collected seed
Fabaceae	Lotus	corniculatus	birdsfoot trefoil	Yugoslavia	dead (no seed)
Fabaceae	Lupinus	albus	white lupin	Yugoslavia	collected seed
Fabaceae	Lupinus	angustifolius	blue lupin	South Africa	dead (no seed)
Fabaceae	Lupinus	concinnus	wild clover	United States	dead (no seed)
Fabaceae	Onobrychis	viciifolia	sainfoin	Bulgaria	collected seed
Fabaceae	Sesbania	sesban	sesban	India	dead (no seed)
Fabaceae	Trifolium	pratense	red clover	USSR	collected seed
Fabaceae	Trifolium	repens	white clover	Italy	collected seed
Fabaceae	Trifolium	alexandrinum	berseem clover	Israel	collected seed
Fabaceae	Vicia	sativa	common vetch	Japan	dead (no seed)
Fabaceae	Vicia	faba	broad bean	Italy	collected seed
Fabaceae	Vigna	unguiculata	cowpea	Iran	dead (no seed)
Fabaceae	Vigna	unguiculata	cowpea	South Africa	dead (no seed)
Fabaceae	Vigna	unguiculata	yard long bean	India	dead (no seed)
Malvaceae	Abelmoschus	moschatus	musk mallow	Benin	dead (no seed)
Poaceae	Acrocerus	macrum	nile grass	South Africa	dead (no seed)
Poaceae	Agropyron	cristatum	wheatgrass	Morocco	collected seed
Poaceae	Bromus	inermis	bromegrass	Ukraine	collected seed
Poaceae	Echinochloa	crus-galli	barnyard	United States	collected seed
Poaceae	Eragrostis	superba	lovegrass	Japan	collected seed
Poaceae	Panicum	maxicum	guineagrass	Panama	dead (no seed)
Poaceae	Pennisetum	schweinfurthii	pearl millet	Sudan	collected seed
Poaceae	Phleum	pratense	timothy	Bulgaria	collected seed
Poaceae	Setaria	italica	foxtail millet	India	collected seed
Poaceae	Sporobolus	fimbriatus	dropseed	South Africa	collected seed
Poaceae	Zea	mays	corn	United States	collected seed
Solanaceae	Capsicum	chacoense	pepper	Argentina	dead (no seed)
Solanaceae	Datura	stramonium	jimson weed	UNKNOWN	collected seed
Solanaceae	Lycopersicon	esculentum	tomato	Surinam	set fruit
Solanaceae	Lycopersicon	pimpinellifolium	currant tomato	Peru	dead (no seed)

EVALUATION OF THE MOBILITY AND THE ACCUMULATION OF TRACE ELEMENTS IN SOIL AND DIFFERENT PLANT SPECIES ENRICHED WITH BIOSOLIDS

G.S. Bañuelos, J. Trent, S. Akohoue, and S. Zambrzuski

OBJECTIVE: Identify the total and soluble trace elements in soil enriched with biosolids and evaluate their uptake into different plant species.

PROCEDURE: High concentrations of trace elements found in biosolids may become soluble and mobile in irrigated agricultural soils. Consequently, they can be absorbed by the crops or move downward in the soil profile. Greenhouse pot experiments were conducted to study the plant uptake of the following trace elements: aluminum, copper, manganese, zinc, cadmium, molybdenum, iron, selenium, boron, sodium, calcium, magnesium. *Brassica napus* (canola), *Festuca arundinacea* (tall fescue), *Medicago sativa* (alfalfa), *Gossypium hirsutum* var. GC 510 (cotton) were grown in 15 L pots, respectively, containing Panoche clay loam [fine-loamy, mixed (calcareous), Thermic typic torriorthents] enriched with 500 g dried biosolids (rate is equivalent to 67 tons ha^{-1}, a commonly applied rate) on the westside soils of central California. Plants were grown in a temperature-controlled greenhouse using a 24° and 18°C (day/ night) temperature regime with a photon flux density of 750-850 μmol $m^{-2}s^{-1}$ from cool white fluorescent lamps for 12 h. Trays were placed under each pot to collect any leachate. The experimental design structure was randomized complete block with five treatments, three blocks, and eight pots per treatment in each block (total of 24 pots per treatment). Treatments consisted of each plant species planted in soils containing biosolids and the same species planted in soils without biosolids; 'controls' were irrigated daily based on water losses by weight (evaporative and transpiration) for each respective treatment throughout the designated growing season. Indian mustard, canola, and cotton were harvested ninety days after first emergence, while tall fescue and alfalfa were first clipped 70 d after emergence, and clipped every 20 d thereafter to a height of 10 cm. Soil and plant samples were taken from each pot at postharvest and analyzed by the inductively coupled plasma spectrometer for the above elements after wet acid digestion of soils and dry ashing of plant material, respectively. Selenium was analyzed by atomic absorption spectrophotometry with continuous hydride generation after $HNO_3/H_2O_2/HCl$ digestion.

RESULTS: Preliminary data are shown in Table 1. In comparison to the perennial crops, canola and cotton accumulated higher concentrations of most measured elements. None of the tested plant species grown in biosolid-enriched soil exhibited any visual toxicity symptoms or decreases in dry matter yield (data not shown). The preliminary results indicate that tall fescue and oats could be safely utilized as animal forage, however, careful consideration to elemental concentrations should be given to leafy plant species, i.e., canola, when considering for use as animal forage

FUTURE PLANS: Complete soil analyses of water extractable and total elements at postharvest. Future greenhouse experiments will include evaluating plant uptake of selected metals in different plant species after applying different rates of biosolids to different soil types. Information collected from greenhouse experiments will be used to determine ideal and nontoxic application rates of biosolids for specific plant species under field conditions.

Table 1. Concentrations of selected elements in above-ground tissue from different plant species grown in soil with or without the addition of biosolids.[†]

Treatment to soil[§]	Plant species[‡]	Total elemental concentrations in shoots:												
		Ca	Mg	Na	Fe	Al	Zn	Cd	Cu	Cr	Co	Mo	B	Se
		(%)			(mg kg^{-1} DM)									
– biosolid	tall fescue	0.5	0.3	0.3	25	36	18	0.2	3.2	0[¶]	0.1	3.1	12	0.1
+ biosolid		1.2	0.8	0.4	43	51	23	0.4	4.6	0[¶]	0.2	5.4	25	0.2
– biosolid	canola	2.3	0.5	0.3	71	49	35	1.2	2.1	0[¶]	0[¶]	3.2	53	0.4
+ biosolid		3.3	0.5	0.4	115	72	100	5.6	7.7	0[¶]	0[¶]	6.6	45	1.5
– biosolid	oats	0.5	0.2	0.2	44	18	15	0.2	3.2	0.1	0.2	6.1	20	0.1
+ biosolid		0.6	0.2	0.3	55	21	18	0.2	4.3	0.1	0.2	6.6	23	0.2
– biosolid	cotton	3.3	0.6	0.2	167	230	62	4.0	3.3	0[¶]	0[¶]	4.5	52	0.3
+ biosolid		3.5	0.6	0.2	200	341	64	4.5	6.5	0[¶]	0[¶]	9.1	61	0.4

[†]Values presented represent the mean from ten replications.
[‡]Values from tall fescue and oats represent the mean concentration from three different clippings.
[§]Treatment biosolid soils ('controls') did not receive any addition of biosolids.
[¶]Trace concentrations.

SELECTED METAL UPTAKE IN APRICOT TREES AND THEIR MOBILITY IN SOIL FERTILIZED WITH COMPOSTED BIOSOLIDS

G.S. Bañuelos, S. Downey, R. Hutmacher, and S. Akohoue

OBJECTIVES: This three year project was initiated to investigate the uptake of heavy metals by apricot trees and the solubility of heavy metals through the soil profile treated twice a year with composted municipal waste (biosolids).

PROCEDURES: This multiple year study was established at the USDA facilities in Fresno, CA in February, 1994. One hundred ninety-two apricot trees (Patterson variety on Marianna root stock) were planted in an experimental plot 1.2 hectares in size (16 rows of trees, 12 trees per row). Tree spacing was 3.3 m between trees and 4 m between rows. A microspray irrigation system was installed in January, 1994, that allowed individual irrigation control of each block of four rows. Each tree is irrigated by two "C" pattern Bowsmith microsprayers which deliver 1.4 L/m in a radius of 1.8 m at a pressure of 103 kPa.

Treatments were three rates of biosolids fertilization based on N concentrations in the biosolids. Composted biosolids contained 7 kg of N per dry ton of biosolids. Biosolids treatments #1, 2 and 3 are 57, 170 and 340 kg N ha^{-1} respectively. Treatment #4 is a control with no biosolids applied to the trees. Treatments were arranged in a split plot design with four replications. Biosolids were applied to the soil surface at the base of each tree, to a radius of 1 m, and incorporated to a depth of 15 cm with a rototiller. Composted municipal waste (biosolids) was donated by Pima-Gro Systems Inc. Applications of biosolids took place twice a year; in the Spring and in the Fall.

Elemental content of composite samples are presented in Table 1. Initial soil samples were taken at the base of each tree at 15 cm depth increments to a depth of 30 cm before and after application of biosolids. Both water extractable ions and acid soluble ions were measured in soil samples. Composite leaf samples (≈50 leaves) were taken from each tree early in the first growing season to obtain baseline leaf concentrations of the elements of interest. This leaf sampling was repeated near the end of the growing season for each year. Soil samples were taken at the base of each tree to depths of 15, 30, and 45 cm before the trees went into the dormant season prior to the next application of biosolids. Treatment effects on tree growth are examined by taking tree trunk diameter measurements each spring and weighing tree prunings in each treatment in the fall. All soil and leaf samples were wet-acid digested with $HNO_3/H_2O_2/HCl$ and analyzed for selected ions by the technique of inductively coupled plasma emission spectrometry using an Emission Spectrometer Plasma 2000.

RESULTS: Both soil and plant samples are presently being analyzed to determine movement and uptake of selected metals. Preliminary results are presented for soil samples in Tables 1.

FUTURE PLANS: Biosolids will continue to be applied twice each year. Soil and leaf samples will be taken before each new application of biosolids. Trunk diameter and pruning weights will be taken to examine treatment effects on tree growth and yield, and the eventual fate of selected metals will be determined with each respective treatment. Desired sustainable rates of biosolid application will be determined for apricots in sandy loam soils.

Table 1. Acid soluble concentrations of ions in soil enriched with biosolids to a depth of 0–30 cm.†

Biosolid Treatment‡	Acid soluble ion concentrations in soil													
	Al	Fe	Ca	Mg	K	P	Na	S	Cd	Cu	Co	Zn	Pb	Se
	(%)							(mg kg^{-1} soil)						
Pre–plant	1.37	1.89	0.19	0.29	0.26	0.02	0.01	90	6.0	14	1.6	27	10	0.1
(no biosolid)	(0.05)	(0.08)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(10)	(0.7)	(0.5)	(0.7)	(4.3)	(1.8)	(0.0)
Post–biosolid I														
K°	1.41	1.92	0.21	0.29	0.25	0.02	0.01	99	6.0	15	1.7	30	11	0.1
	(0.06)	(0.05)	(0.05)	(0.03)	(0.01)	(0.00)	(0.00)	(65)	(0.3)	(1.5)	(0.2)	(2.1)	(2.1)	(0.0)
Low	1.42	1.92	0.25	0.30	0.25	0.03	0.01	100	6.5	16	1.9	40	14	0.1
	(0.06)	(0.06)	(0.03)	(0.00)	(0.00)	(0.00)	(0.00)	(15)	(0.04)	(1.8)	(0.06)	(3.5)	(2.0)	(0.0)
Med.	1.44	2.00	0.28	0.33	0.26	0.04	0.02	200	6.9	19	2.0	74	15	0.2
	(0.05)	(0.07)	(0.03)	(0.02)	(0.00)	(0.00)	(0.00)	(15)	(0.4)	(2.1)	(0.5)	(14)	(1.9)	(0.01)
High	1.43	2.01	0.42	0.36	0.27	0.07	0.03	285	8.1	24	2.7	91	16	0.3
	(0.06)	(0.09)	(0.07)	(0.03)	(0.02)	(0.01)	(0.00)	(21)	(0.3)	(2.7)	(0.03)	(23)	(2.2)	(0.0)

†Values are means and standard error in parenthesis from 10 soil samples.
‡Application rates of biosolids; K° (none), low, medium, and high (rates are described in procedures).

Table 2. Water souble concentrations of ions in soil enriched with biosolids to a depth of 0–30 cm.†

Biosolid Treatment‡	Water soluble ion concentrations in soil																	
	Al	Fe	Ca	Mg	K	P	Na	S	Cd	Cu	Co	Zn	Pb	Cu	Se	B	pH	EC
	(mg L^{-1})																	
Pre–plant	10	0.3	38	12	21	11	175	70	*§	*	*	*	*	*	*	0.4	6.2	2.1
(no biosolid)	(0.8)	.(00)	(4.1)	(6.1)	(4.6)	(1.2)	(29)	(10)	*	*	*	*	*	*	*	(00)	(0.1)	(0.1)
Post–biosolid I																		
K°	9	0.1	46	23	40	13	165	91	*	0.1	*	0.1	0.1	0.1	*	0.2	6.3	2.3
	(11)	(00)	(5.2)	(9.1)	(7.1)	(1.0)	(34)	(11)	*	(00)	*	(00)	(00)	(00)	*	(00)	(0.1)	(0.2)
Low	9	0.1	314	131	88	17	179	125	*	0.2	*	0.1	0.1	0.1	*	0.3	6.3	2.3
	(0.9)	(00)	(54)	(16)	(10)	(2.0)	(45)	(13)	*	(00)	*	(00)	(00)	(00)	*	(00)	(0.1)	(0.2)
Med.	9	0.2	378	180	121	18	450	1225	*	0.2	*	0.2	0.2	0.1	*	0.4	6.4	2.7
	(0.8)	(00)	(90)	(31)	(9.5)	(1.3)	(89)	(95)	*	(00)	*	(00)	(00)	(00)	*	(00)	(0.2)	(0.3)
High	11	0.2	445	220	145	28	776	2000	*	0.2	*	0.3	0.5	0.1	0.1	0.5	6.5	3.4
	(1.6)	(00)	(100)	(42)	(14)	(2.9)	(99)	(131)	*	(00)	*	(00)	(00)	(00)	(00)	(00)	(0.2)	(0.5)

†Values are means and standard error in parenthesis from 10 soil samples.
‡Application rates of biosolids; K° (none), low, medium, and high.
§*Trace concentrations of tested ion.

Table 3. Selected ion concentrations in leaf samples of apricots grown in biosolid–enriched soils at two different times.†

Biosolid Trt.*	S	P	Ca	Mg	K	Al	Fe	Na	Cd	Cu	Co	Zn	Pb	Mn	Se	B
	(%)								(mg kg^{-1} DM)							
Collected at 6/95																
K°	0.1	0.2	1.0	0.3	3.3	278	290	279	0.5	12	0.1	35	3.3	74	*§	25
	(0.01)	(0.02)	(0.0)	(0.05)	(0.33)	(27)	(36)	(41)	(00)	(2.1)	(00)	(9.5)	(0.5)	(7.6)	*	(0.3)
Low	0.1	0.2	1.1	0.3	3.4	295	265	317	0.5	12	0.2	38	6.6	82	*	27
	(0.01)	(0.02)	(0.11)	(0.04)	(0.31)	(31)	(20)	(26)	(00)	(1.9)	(00)	(6.4)	(0.2)	(8.9)	*	(0.6)
Med.	0.1	0.2	0.9	0.3	3.7	307	321	331	0.7	12	0.4	43	8.1	90	*	27
	(0.01)	(0.03)	(0.10)	(0.03)	(0.42)	(32)	(21)	(52)	(00)	(7.0)	(00)	(6.8)	(1.0)	(9.4)	*	(0.4)
High	0.14	0.3	0.9	0.4	4.1	410	370	340	0.9	12	0.6	47	11	108	*	30
	(0.01)	(0.02)	(0.14)	(0.02)	(0.47)	(35)	(52)	(31)	(00)	(2.1)	(00)	(5.9)	(1.1)	(11)	*	(0.4)
Collected at 10/95																
K°	0.16	0.12	1.1	0.2	2.9	308	394	36	*	6.1	*	100	2.5	15	*	29
	(0.02)	(00)	(0.1)	(0.0)	(0.03)	(21)	(29)	(00)	*	(0.5)	*	(10)	(0.4)	(0.4)	*	(0.2)
Low	0.17	0.11	1.2	0.3	3.0	312	421	49	*	6.3	*	115	4.7	18	*	32
	(0.01)	(00)	(0.2)	(0.01)	(0.07)	(34)	(38)	(4.7)	*	(0.4)	*	(11)	(0.6)	(0.3)	*	(0.7)
Med.	0.17	0.12	1.2	0.3	3.1	326	612	90	*	7.1	*	124	4.9	19	0.1	34
	(00)	(00)	(0.2)	(0.02)	(0.1)	(49)	(49)	(3.8)	*	(00)	*	(16)	(0.5)	(0.7)	(00)	(0.5)
High	0.17	0.13	1.2	0.3	3.2	347	615	95	*	7.5	*	131	10	21	0.1	37
	(00)	(00)	(0.2)	(0.02)	(0.09)	(46)	(29)	(6.1)	*	(0.4)	*	(12)	(0.4)	(1.0)	(00)	(0.2)

†Values are means and standard error in parenthesis from 10 soil samples.
‡Application rates of biosolids; K° (none), low, medium, and high.
§*Trace concentrations were measured.

RESPONSE OF COTTON AND KENAF IRRIGATED WITH 'BORON-AMENDED' WATER

G.S. Bañuelos, B. Mackey, C. Cook, S. Akohoue, S. Zambrzuski and P. Samra

OBJECTIVE: The objectives of this study were to investigate the growth responses of kenaf and cotton irrigated with B-amended water under greenhouse conditions.

PROCEDURE: Boron uptake distribution and B tolerance of two plant species were investigated under greenhouse conditions in Fresno, California, between April 1993 and October 1993. Kenaf (*Hibiscus cannabinus* L. var. Indian) and cotton (*Gossypium hirsutum* L. var. GC510) were grown from seed in 18-L plastic pots, filled with 15 kg air-dried Panoche Clay loam [fine-loamy, mixed (calcareous), thermic Typic Torriorthents]. It was passed through a 2 mm mesh sieve after air drying. The pH of the soil was 7.7 and the electrical conductivity (EC) was 7.8 dS m^{-1} and extractable B was <0.25 mg L^{-1} in the soil saturation extract. Seven to ten days after plant emergence, each pot for each species was thinned to five plants, spaced approximately 8 cm apart. The plants were initially grown in temperature-controlled greenhouses using a 21°C and 18°C day/night temperature regime with a photon flux density of 600 μmol $m^{-2}s^{-1}$ from natural sunlight. Forty-five days later as summer progressed, the temperature regime ranged from 30°C and 24°C day/night with an average photon flux density of 850 μmol $m^{-2}s^{-1}$. Initially 25 ml of 0.1 strength Hoagland nutrient solution No. 2 without B was added weekly to each pot. Forty five days later this nutrient solution strength was increased to 25 ml of 0.25 strength Hoagland nutrient solution. A randomized complete block design with two treatments and three blocks (three greenhouses) was used for the greenhouse study.

Treatments consisted of irrigating both plant species with either: 1) water containing 7.5 mg B L^{-1} added as boric acid ('B-treated water') or, 2) water containing less than 0.25 mg B L^{-1} referred to as 'control water'. There were a total of 12 randomly placed pots per treatment per species in each greenhouse. Daily weighing of these pots gave approximate evaporative soil water losses for each greenhouse. All pots, including those without plants, were irrigated with the respective water B treatment when the soil water loss was estimated to be between 50-60% (determined by the weighing of pots with and without plants). The experiment was designed to reduce the interaction between soil water regime and applied B to the soil. 'Boron-treated water' or 'control water' was applied to replace water lost by transpiration and evaporation, thus minimizing the production of any drainage water, and maintaining a low moisture stress in the potted soils. The first application of B occurred 20 d after plant emergence. Any leachate that did occur was collected on a per pot basis and reapplied to the pot from which it was collected.

Plant height and node counts were obtained on a weekly basis for both plant species grown under both treatments. Composite young leaves of both species were collected five times (in 7 d intervals beginning at day 75 after emergence) during the course of the experiment. Sixty days after initial application of 'B-treated water' it was decided to add 'control water' in place of B-treated water for 14 d to both treatments, because apparent B-toxicity symptoms were occurring in leaves from both species. One hundred fifty days after emergence, kenaf and cotton were harvested and separated into the following plant tissue categories: older and younger leaves, upper and lower stalk, roots, lint, and seeds. Five approximately 500 g soil samples were taken from each pot prior to planting and after harvest.

RESULTS: *Dry matter yield.* Table 1 presents the DM yield of each respective plant organ of both kenaf and cotton irrigated with B-laden and fresh water. The overall plant DM decreased more severely for kenaf (≈50%) than cotton

(≈30%) with the irrigation of B-treated water (Table 1). Dry matter of most of the individual plant organ tissues were significantly affected by the treatment of B-laden water at the $P<0.001$ level for kenaf. Correlation coefficients between DM yield and tissue B concentrations indicate a significant relationship between dry matter yield and tissue B concentrations in both plant species (data not presented). Cotton lint yields were about 40% lower in plants irrigated with B-laden water (Table 2). Table 2 shows that B-treated water did not significantly affect the plant height or the number of developing nodes on either kenaf or cotton during the designated time of measurement. However, the length of the internodes was visually shorter in kenaf irrigated with B-treated water (data not shown); consequently, kenaf irrigated with B-laden water was approximately 16% shorter than kenaf irrigated with fresh water. Both plant species, especially kenaf, eventually showed signs of B toxicity on the leaf margins. Kenaf irrigated with B-treated water had thicker stalks than control kenaf (data not shown). Cotton irrigated with fresh water had 20% more blooms and bolls than cotton irrigated with B-treated water (data not shown). Insect infestation was consistently higher in kenaf and cotton irrigated with fresh water (data not shown).

Tissue boron concentrations

The leaves of both species accumulated the greatest amount of B and the young stems the least (Table 1). Composite young leaf samples for each species collected five times from cotton and kenaf plants irrigated with B-treated water, had the following ranges of B tissue concentrations: cotton - 300 to 800 mg B kg^{-1} DM and kenaf - 500 to 1400 mg B kg^{-1} DM.

FUTURE PLANS: Continue B analyses of selected samples. A manuscript is presently under preparation.

Table 1. Dry matter production and boron concentrations detected from plant organ tissues of kenaf and cotton irrigated with boron–laden water and for fresh water.†

Plant Species	Water Treatment	Plant organ‡	*Greenhouse I*		*Greenhouse II*		*Greenhouse III*		*Greenhouse Summary*§	
			Dry matter (g pot^{-1})	Boron content (mg B)	Dry matter (g pot^{-1})	Boron content (mg B)	Dry matter (g pot^{-1})	Boron content (mg B)	Dry matter (g pot^{-1})	Boron content (mg B)
Kenaf	Control	OL	44(3)	3.0(0.4)	52(2)	4.0(0.2)	26(4)	2.0(0.3)	41(3)	2.0(0.3)
"	"	YL	57(3)	3.0(0.2)	48(4)	2.0(0.3)	47(2)	4.0(0.2)	51(3)	3.0(0.2)
"	"	YS	26(2)	0.4(0.1)	26(2)	0.5(0.1)	33(4)	1.0(0.3)	28(3)	0.6(0.2)
"	"	OS	58(3)	0.5(0.1)	61(3)	1.0(0.3)	65(4)	1.0(0.1)	61(3)	0.8(0.2)
"	"	R	52(5)	0.4(0.1)	53(5)	1.0(0.2)	53(7)	1.0(0.2)	53(6)	0.8(0.2)
"	"	*Total*	*237(14)*	*7.3(1)*	*240(15)*	*9.0(2)*	*224(12)*	*9.0(0.3)*	*234(14)*	*8.0(1)*
Kenaf	Boron	OL	24(3)	28(3)	25(3)	26(3)	21(2)	20(3)	23(3)	25(3)
"	"	YL	18(2)	22(3)	11(1)	11(2)	22(0.6)	30(2)	17(1)	21(2)
"	"	YS	13(2)	0.5(0.1)	11(0.7)	0.7(0.1)	12(1)	0.7(0.1)	12(1)	0.6(0.1)
"	"	OS	30(3)	1.0(0.1)	33(1)	1.0(0.2)	35(2)	2.0(0.08)	33(2)	2.0(0.1)
"	"	R	21(2)	1.0(0.1)	16(1)	1.0(0.1)	18(4)	1.0(0.1)	18(2)	1.0(0.1)
"	"	*Total*	*106(7)*	*52(4)*	*96(7)*	*41(3)*	*108(6)*	*54(5)*	*103(7)*	*49(4)*
Cotton	Control	OL	34(1)	3.0(0.3)	21(6)	2.0(0.6)	38(3)	2.0(0.3)	31(3)	2.0(0.4)
"	"	YL	8.0(0.8)	0.4(0.1)	9.0(2)	0.5(0.1)	19(4)	2.0(0.5)	12(2)	2.0(0.2)
"	"	YS	2.0(0.4)	0.4(0.0)	2.0(0.3)	0.09(0.0)	8.0(0.6)	0.2(0.0)	4.0(0.4)	0.1(0.0)
"	"	OS	15(2)	0.3(0.1)	26(2)	0.3(0.1)	17(0.9)	1.0(0.5)	19(2)	0.5(0.2)
"	"	R	12(1)	0.2(0.1)	10(1)	0.8(0.2)	10(0.5)	0.4(0.0)	11(0.8)	0.5(0.2)
"	"	*Total*	*71(5)*	*4.4(0.2)*	*68(4)*	*4.0(0.1)*	*92(4)*	*6.0(0.3)*	*77(4)*	*5.0(0.2)*
Cotton	Boron	OL	20(3)	8.0(1)	20(3)	8.0(1)	13(0.6)	4.0(0.2)	18(2)	7.0(0.7)
"	"	YL	10(0.1)	4.0(0.7)	8.0(0.4)	3.0(0.5)	9.0(1)	3.0(0.5)	9.0(2)	3.0(0.6)
"	"	YS	2.0(0.4)	0.1(0.0)	3.0(0.2)	0.7(0.0)	6.0(0.4)	0.2(0.02)	4.0(0.3)	0.1(0.0)
"	"	OS	20(2)	0.4(0.1)	23(2)	0.4(0.1)	19(2)	0.6(0.1)	21(2)	0.5(0.2)
"	"	R	13(0.5)	0.8(0.1)	12(0.2)	0.8(0.2)	10(0.8)	0.3(0.1)	12(0.5)	0.6(0.1)
"	"	*Total*	*65(7)*	*13(0.6)*	*66(6)*	*12(1)*	*57(5)*	*8.0(0.3)*	*62(6)*	*12(0.6)*

†Each value represents the mean from a minimum of eight replications followed by the standard error in parenthesis.

‡Detailed description of plant organs is described in methods and materials; OL = old leaves, YL = young leaves, YS = young stem, OS = old stem, R = roots.

§Values represent the mean from all three greenhouses.

Table 2. Total above-ground dry matter and different growth parameter at harvest of kenaf and cotton irrigated with boron-laden and fresh water.[†]

Plant Species	Water Treatment	Height (cm)	Nodes (#)	Total above-ground dry matter[‡] (g plant^{-1})	Total dry-cotton lint (g plant^{-1})
Greenhouse I					
Kenaf	Control	104(4)	66(4)	185(8)	NA[§]
"	Boron	88(1)	62(2)	86(4)	
Cotton	Control	36(3)	14(1)	56(2)	36(2)
"	Boron	40(3)	13(1)	52(3)	20(1)
Greenhouse II					
Kenaf	Control	103(3)	63(2)	187(7)	NA
"	Boron	93(3)	67(2)	81(4)	
Cotton	Control	39(3)	14(3)	58(3)	38(2)
"	Boron	42(3)	17(1)	54(4)	25(2)
Greenhouse III					
Kenaf	Control	110(2)	66(3)	170(11)	NA
"	Boron	85(10)	63(5)	89(2)	
Cotton	Control	41(3)	15(2)	83(2)	37(1)
"	Boron	35(3)	14(1)	46(3)	23(2)

[†]Each value represents the mean from a minimum of eight replications followed by the standard error in parenthesis.
[‡]Not including the lint for the cotton plants.
[§]NA = not applicable.

TECHNOLOGY TRANSFERS

WATER MANAGEMENT RESEARCH LABORATORY'S MISSION IN EDUCATION

S.S. Vail

Our location began a program (1990) of educating our local high school students in the role science plays in agriculture.

We host an annual Open House, usually over a 2 day period, with an average attendance of approximately 500 students. The students are placed in groups (<25 students) and each group sees from 3-4 exhibits/presentations covering diverse topics, such as crop water use efficiency, biological control, fruit breeding and genetics, postharvest technology, and entomology. Students are encouraged to ask questions.

The students are given information on the educational backgrounds of the Scientists so they can see how important backgrounds of math and science are in future careers. Abstracts of all the presentations are made available to the teachers, as well as information on careers in agriculture. Information on our High School Summer Research Apprenticeship Program (available to students 16 years of age and older) is also made available to the teachers at this time.

Refreshments are served, typically commodities our valley agricultural community produces such as nuts, raisins, and fruit.

DISSEMINATING DRIP IRRIGATION TECHNOLOGY AND MAKING THE WMRL INTERNATIONALLY ACCESSIBLE USING THE INTERNET

R. M. Mead, R. Soppe, J. Ayars, J. Pier, T. M. Stein

OBJECTIVES: To expand the level of communication in the international community by discussing and presenting the technology of drip irrigation through an electronic mailing list on the Internet.

PROCEDURES: Electronic mail (E-mail) distribution lists have become popular on the Internet in the past several years. An E-mail discussion list is usually an unmoderated group of individuals discussing certain topics of mutual interest, whereby their comments, questions or essays are distributed among co-subscribers using the Internet. All subscribers of a particular list get the same E-mail from a listserver (or host) computer. The E-mail distribution list also needs a main computer to collect incoming mail and distribute it to the subscribers.

In July 1994 an email distribution list specifically for drip irrigation discussion was created by a host computer at the University of Nebraska at Lincoln. With the help of the list owner of AGMODELS-L, Dr. Jerome Pier, a site was found at the computer of the University of Nebraska-Lincoln. The list was officially termed "Trickle-L" and R. Mead took responsibility of becoming the list owner.

RESULTS: At the end of 1994, 142 subscribers had logged on to Trickle-L. Eighty-four percent were from the U.S., 6% from Australia, and the remaining 10% included subscribers from Australia, Belgium, Canada, Germany, Japan, New Zealand, The Netherlands, Portugal, South Africa, Thailand and the U.K. Subscriber background varied from grape and tree growers, hops farmers, greenhouse managers, college professors, graduate students, journalists, sales people, extension specialist, organic farmers and scientists. Topics of discussion included: chlorine use, fertigation, soil moisture sensors, root intrusion prevention of SDI systems, emitter clogging, vectored irrigation and high frequency irrigation.

In December 1994, the 1992 WMRL progress report was installed on an anonymous file transfer protocol (ftp) site at California Agricultural Technology Institute on the campus of California State University Fresno. This eventually meant that the WMRL/Internet connection was expanding by having the CATI ftp site accessible from the Virtual Library of Irrigation on the World Wide Web established by Mr. Thomas-M Stein at the University of Kassel in Germany. Archives of Trickle-L can also be found with a *Gopher* at SUNSITE.UNC.EDU.

FUTURE PLANS: The Internet aspect of the Water Management Research Laboratory will grow even more by establishing a homepage on the World Wide Web. The WMRL homepage will eventually include photo tours of the WMRL, research site descriptions, a library of WMRL progress reports, list of WMRL publications, archives of Trickle-L, subscription information for Trickle-L, a bibliography of drip irrigation technology and links to other agriculturally related Web sites.

SUPPORT LABORATORIES

ANALYTICAL CHEMISTRY LABORATORY

T.J. Pflaum, C.A. Ament, and G.S. Bañuelos

The main purpose of the Analytical Chemistry Laboratory is to support field research projects for the Water Management Research Laboratory. The types of samples analyzed include soils, water, and plant tissue. The total number of analyses performed for 1994 was 38,905. The total number of all samples was 5,005.

During the year of 1994, 30,610 analyses for cations and anions were performed on a total of 3,437 soil samples. In addition to the soil samples, 585 water and 983 plant tissue samples were examined for a total of 5,918 and 2,377 analyses, respectively.

Colleen Ament left the chemistry laboratory in September of 1994. Sara Larson was hired in December of 1994 to work in the chemistry laboratory.

ELECTRONICS ENGINEERING LABORATORY

D. Clark, A. Nevarez, and F. Piyasil

The Electronics Engineering Laboratory provides electronic and computer services in support of Water Management Research Projects. Work is dominated by the design, programming, installation, maintenance, data collection and processing of remote irrigation control systems. The Electronics Laboratory currently manages fifteen data acquisition systems including eleven automated irrigation projects. The past year's work includes the following.

The irrigation system for the newly constructed lysimeters in Parlier was designed. An ultrasonic sensor was tested for measuring water level in a groundwater supply tank. The pumps, valves, sensors, datalogger, and communications equipment were installed. Most of the wiring work was completed.

At the West Side Field Station, fertilizer valve controls were added to the 54 Plots Project. The 36 Plots Datalogger Program was modified to control two of the treatments with a separate crop coefficient. An electronic scale and a datalogger were repaired after being damaged by water leaking into the south lysimeter. Communications equipment for the south lysimeter, 54 Plots, and 36 Plots Projects was also repaired.

The irrigation program in Brawley was modified to try and correct a pump priming problem. The irrigation control for field F3 was changed from moisture sensors to weather station evapotranspiration. The irrigation control for the Davis Project was changed from evaporation pan to an ET gage. The Britz project ended and the datalogger system, evaporation pan, sensors, and wiring were removed.

The macro programs for the automated data collection and processing system were rewritten and condensed to make the system more manageable. A power control for the printer was fabricated so the daily reports could be printed unattended at night.

Other work involved the setup of several new computers, routine maintenance, and various data processing assignments. Collaboration on the design of the San Joaquin Valley Agricultural Science Center was begun.

PUBLIATIONS

MANUSCRIPTS PUBLISHED IN 1994

Hutmacher, R.B., H.I. Nightingale, D.E. Rolston, J.W. Biggar, F. Dale, S.S. Vail, D. Peters. 1994. Growth and yield responses of almond (*Prunus amygdalus*) to trickle irrigation. Irrigation Science 14(3):117-126.

Bañuelos, G.S., P. Bueselinck. 1994. Remediation of selenium and boron contaminated soil with *Lotus corniculatus* L. Proceedings, The First International Lotus Symposium, St. Louis, MO, March 22-24, pp. 167-171.

DeTar, W.R., C.J. Phene, D.A. Clark. 1994. ARTICLE. Drip vs. Furrow Irrigation. Cotton Grower Mid-April, p. 16.

Bañuelos, G.S., S. Akohoue. 1994. Comparison of microwave digestion with block digestion for selenium and boron analysis in plant tissues. Communications in Soil Science and Plant Analysis 25(9 & 10):1655-1670.

Watson, M.C., G.S. Bañuelos, J.W. O'Leary, J.J. Riley. 1994. Trace element composition of *Atriplex* grown with saline drainage water. Agriculture Ecosystems & Environment 48(2):157-162.

Hutmacher, R.B., C.J. Phene, K.R. Davis, J.E. Ayars, W.R. DeTar. 1994. ARTICLE. Irrigation Systems Overview. An excerpt from paper presented at the 1st International Cotton Production Research Conference, Brisbane, Australia. California-Arizona Cotton, May Issue, 30(5):6-7, 22.

Ayars, J.E. and D.W. Meek. 1994. Drainage load-flow relationships in arid irrigated areas. Transactions of the ASAE 37(2):431-437.

Hutmacher, R.B., C.J. Phene, K.R. Davis, M.S. Peters, T.J. Pflaum, S.S. Vail, C.A. Hawk, A.D. Bravo, D. Clark, D.A. Ballard, N. Hudson, T.A. Kerby, M. Keeley. 1994. ACALA and PIMA cotton water relations and nutrient management under subsurface drip irrigation. Proceedings, Beltwide Cotton Conference, San Diego, CA, January 5-8, 3:1355-1359.

DeTar, W.R., C.J. Phene, D.A. Clark. 1994. Subsurface drip vs. furrow irrigation: 4 years of continuous cotton on sandy soil. Proceedings, Beltwide Cotton Conference, San Diego, CA, January 5-8, 1:542-545.

Mead, R.M., I.C. Paltineanu, J.E. Ayars, J. Liu. 1994. Capacitance probe use in soil moisture measurements. Presentation, ASAE Paper No. 942122, Kansas City, MO., June 20-22.

Bañuelos, G.S., S. Zambrzuski, S. Akohoue, S. Downey. 1994. Bioremediation of seleniferous soils with selected plants. Proceedings, 15th World Congress of Soil Science, Volume 4b:224-225, Commission III: Poster Sessions, Acapulco, Mexico, July 10-16.

Ben-Asher, J., G. Cardon, D. Peters, D.E. Rolston, C.J. Phene, J.W. Biggar, and R.B. Hutmacher. 1994. Determining almond root zone from surface carbon dioxide fluxes. ASA Soil Science Society of America Journal 58(3):930-934, May/June 1994.

Ben-Asher, J., G.E. Cardon, D. Peters, D.E. Rolston, J.W. Biggar, and C.J. Phene. 1994. Determining root activity distribution by measuring surface carbon dioxide fluxes. ASA Soil Science Society of America Journal 58(3):926-930, May/June 1994.

Bañuelos, G.S. 1994. EXTENDED ABSTRACT. Managing high levels of B and Se with trace element accumulator crops. Symposium, Emerging Technologies in Hazardous Waste Management VI, 1994 Book of Abstracts, Volume II of II, pp. 1344-1347, Atlanta, GA, September 19-21.

Hutmacher, R.B., C.J. Phene, R.M. Mead, K.R. Davis, S.S. Vail. 1994. Fertigiation management with subsurface drip irrigation: Principles and precautions. Proceedings, Micro Irrigation Workshop and Trade Show, Santa Maria, CA, October 19, pp. 13-23.

Ayars, J.E. 1994. Managing drainage systems in arid irrigated areas. Proceedings, Irrigation Association International Exposition and Technical Conference, pp. 235-241, Atlanta, GA, November 5-8.

Ayars, J.E. and R.B. Hutmacher. 1994. Crop coefficients for irrigation scheduling in the presence of shallow ground water. Irrigation Science 15(1):45-52.

Bañuelos, G.S. 1994. Managing high levels of B and Se with trace element accumulator crops. emerging Technologies in Hazardous Waste Management VI. Sept. 19-21, 1994. Atlanta, GA. 2:1344-1348.

Bañuelos, G.S., B. Mackey, L. Wu, S. Zambrzuski, and S. Akohoue. 1994. Bioextraction of soil boron by tall fescue. J. Ecology and Ecotoxicology 31:1-7.

Bañuelos, G.S., N. Terry, A.M. Zayed, and L.L. Wu. 1994. Managing high soil Se with bioremediation *In*: Decades later: a time for reassessment (eds) G.E. Schuman and G.F. Vance ASSMR. Gillette, Wyoming pp. 394-405.

Wu, L., Jianguo, Chen, K.K. Tanji, and G.S. Bañuelos. 1994. Distribution and biomagnification of Se in a restored upland grassland contaminated by Se from agricultural drainwater. Environmental Toxicology and Chemistry. 14:733-742.

MANUSCRIPTS ACCEPTED FOR PUBLICATION 1995

G.R. Jayaweera, T.K. Tokunaga, W.T. Frankenberger, Jr., N. Terry , and G.S. Bañuelos. 1995. Selenium remediation in soils, sediments and waters. *In*: Biogeochemistry of Toxic Trace Elements in soils, Waters and Sediments.

Ayars, J.E. 1995. EXTENDED ABSTRACT. Managing plant water uptake from shallow saline groundwater. Proceedings, Clean Water-Clean Environment-21st Century, Kansas City, MO, March 5-8, Volume III: Practices, Systems and Adoption.

Hutmacher, R.B., H.I. Nightingale, S.S. Vail, F. Dale, D.E. Rolston, D.W. Peters, P.H. Brown, A.D. Bravo, J.W. Biggar. 1995. Salinity and Boron distribution in microirrigated almonds: soil and plant accumulations. Proceedings, Fifth International Microirrigation Congress, Orlando, FL, April 2-6.

Ayars, J.E., C.J. Phene, R.A. Schoneman, B. Meso, F. Dale, J. Penland. 1995. Impact of bed location in the operation of subsurface drip irrigation systems. Proceedings, Fifth International Microirrigation Congress, Orlando, FL, April 2-6.

Hutmacher, R.B., C.J. Phene, K.R. Davis, S.S. Vail, T.A. Kerby, M. Peters, C.A. Hawk, M. Keeley, D.A. Clark, D. Ballard, N. Hudson. 1995. Evapotranspiration, fertility management for subsurface drip Acala and Pima cotton. Proceedings, Fifth International Microirrigation Congress, Orlando, FL, April 2-6.

Hutmacher, R.B., C.J. Phene, K.R. Davis, S.S. Vail, T. Pflaum, M.S. Peters, C.A. Hawk, T.A. Kerby, M. Keeley. 1995. Nitrogen uptake of Acala and Pima cotton under high-yield, drip irrigation conditions. Proc. Beltwide Cotton Conf.

Hutmacher, R.B., R.M. Mead, C.J. Phene, D. Clark, P. Shouse, S.S. Vail, R. Swain, M. van Genuchten, M.S. Peters, C.A. Hawk. 1995. Subsurface drip and furrow irrigation of alfalfa in the Imperial Valley. Proc. Drip-irrigated Forage Production Conf., Midland, TX., October 24, 1995.

Mead, R.M., J.E. Ayars, J. Liu. 1995. Evaluating the influence of soil texture, bulk density and soil water salinity on a capacitance probe calibration. Presentation, ASAE Paper No. 953264, Chicago, IL, June 18-23.

Bañuelos, G.S., N. Terry, A.M. Zayed, L.L. Wu. 1995. Managing high soil selenium with phytoremediation. pp. 394-405, *In*: G.E. Schuman and G.F. Vance (Eds), Decades later: A time for reassessment, Volume 1, Selenium, Mining, Reclamation and Environmental Impacts. American Society for Surface Mining and Reclamation (ASSMR), Gillette, WY, June 5-8.

Wu, L., J. Chen, K. K. Tanji, G.S. Bañuelos. 1995. Distribution and biomagnification of selenium in a restored upland grassland contaminated by selenium from agricultural drainwater. Environmental Toxicology and Chemistry.

Ayars, J.E., R.M. Mead, I.C. Paltineanu, J. Liu. 1995. Radioactive versus capacitance techniques for measuring soil moisture. Proceedings, International Symp. on Nuclear and Related Techniques in Soil/Plant Studies on Sustainable Agriculture and Environmental Preservation, Vienna, Austria, October 17-21, 1994.

Bañuelos, G.S., B. Mackey, L. Wu, S. Zambrzuski and S. Akohoue. 1995. Bioextraction of soil boron by tall fescue. Journal of Ecoloxicology and Environmental Safety.

Ayars, J.E., M.E. Grismer and J.C. Guitjens. 1995. Water quality as a design criteria in irrigation and drainage water management systems. Proceedings, ASCE 1st International Conference on Water Resources Engineering, San Antonio, TX, August 14-18.

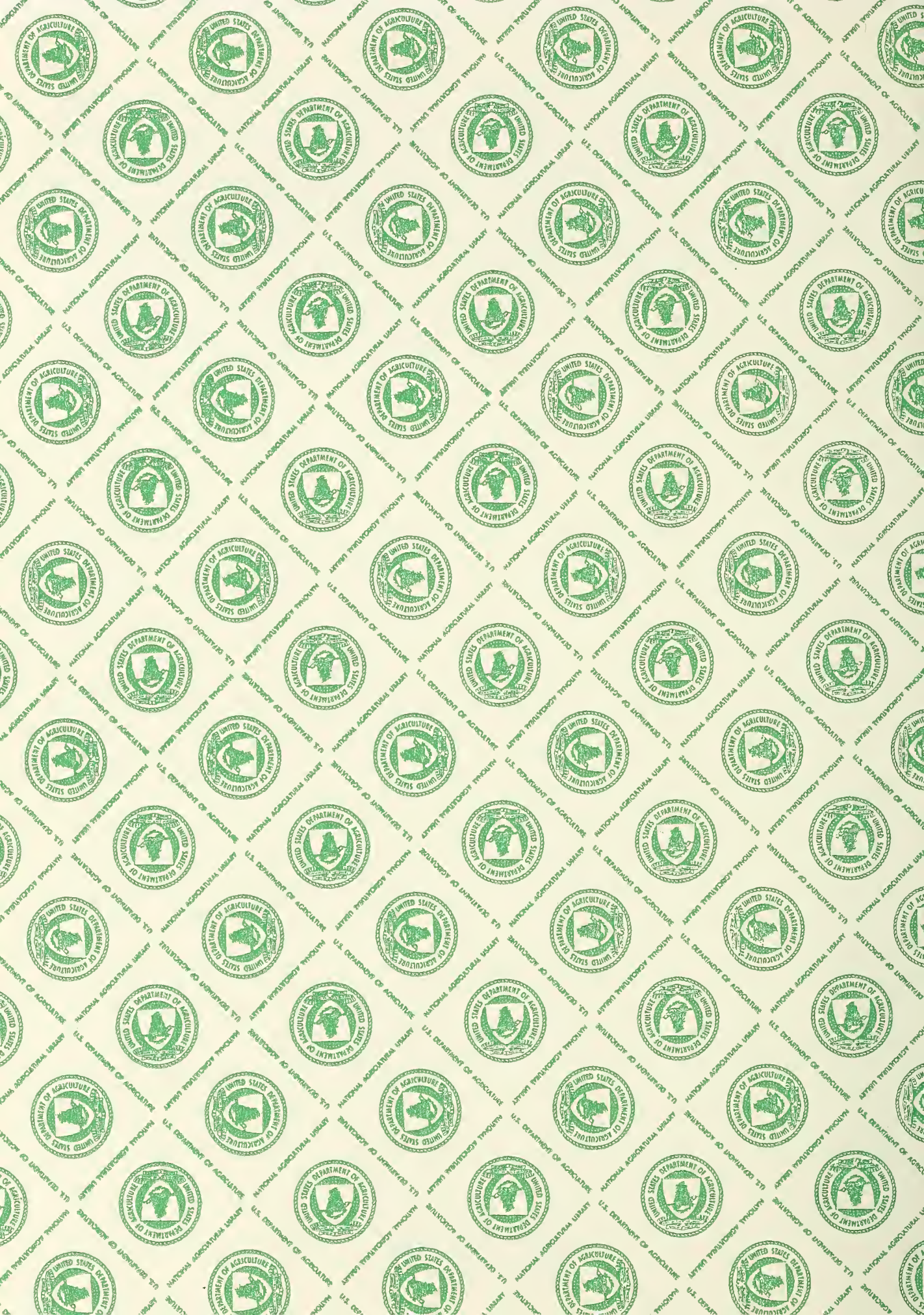
Bañuelos, G.S., L.H. Aung, S. Akohoue, D. Fouse. 1995. Effects of Sodium 2,3-dichloroisobutyrate (DCB) on dry matter and sugar distribution in the organs of *Brassica juncea* L. Czern. ΦYTΘN International Journal of Experimental Botany.

El-Mowelhi, N.M., M.S.M. Abo Soliman, H.A. Shams El-Din, J. Ayars, and S.A. Hasanein. 1995. On farm water management in soils of Kafr El-Sheikh. II. Effect of land levelling practices and stream size under furrow irrigation system. Proceedings, Conference on Farm Irrigation and Agroclimatology, Soils and Water Research Institute, Agricultural Research Center, Giza, Egypt, January 2-4.

Bañuelos, G.S., L. Aung, S. Akohoue, and D. Fouse. 1995. Effects of DCB on dry matter and sugar distribution in the organs of *Brassica juncea*. J. Expt. Botany.

Bañuelos, G.S., A. Zayed, N. Terry, B. Mackey, L. Wu, S. Akohoue, and S. Zambrzuski. 1995. Accumulation of selenium by different plant species grown under increasing salt regimes. Plant and Soil.

Bañuelos, G.S. and H.A. Ajwa. 1995. Trace elements in soils and plants: an overview. J. of Environ. Sci. and Health.

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